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A MECHANICAL SOLUTION OF A LITERARY PROBLEM.

By Dr. T. C. MENDENHALL.

THE title given to this paper, chosen after much hesitation and with no little reluctance, is not to be looked upon as an assumption of the definite and final solution of the principal problem to which attention has been directed. As a matter of fact I have hoped to conceal, for at least a page or two, the identity of this principal problem, in order that no well intentioned and good natured reader might be driven away by what is a very general, not altogether reasonable, but quite natural, prejudice. Whatever may be thought of the problem or of the importance of its solution, it is believed that the method here suggested and applied will be found to be of interest and, possibly, of considerable value in certain linguistic studies.

Nearly twenty years ago I devised a method for exhibiting graphically such peculiarities of style in composition as seemed to be almost purely mechanical and of which an author would usually be absolutely unconscious. The chief merit of the method consisted in the fact that its application required no exercise of judgment, accurate enumeration being all that was necessary, and by displaying one or more phases of the mere mechanism of composition characteristics might be revealed which the author could make no attempt to conceal, being himself unaware of their existence. It was further assumed that, owing to the well-known persistence of unconscious habit, personal peculiarities in the construction of sentences, in the use of long or short words, in the number of words in a sentence, etc., will *in the long run* manifest themselves with such regularity that their graphic representation may become a means of identification, at least by exclusion. In the present

consideration the application of the method has been restricted to a study of the relative frequencies of the use of words of different lengths.

The method of procedure is simple and will be best explained by an example. One thousand words in 'Vanity Fair,' taken in consecutive order of course, were counted and classified as to the number of letters in each with the following result:

Letters—	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Words —	25	169	232	187	109	78	79	48	28	20	10	10	2	3

The graphic exhibition of this result is made by the well-known method of rectangular coordinates, using the number of letters in a word as the abscissa and the corresponding number of words in a thousand as the ordinate. On a sheet of 'squared' paper the numbers showing letters in each word, 1, 2, 3, 4, etc., are placed along the horizontal line and on the vertical above each of these is put a point whose distance from the base shows the number of corresponding words in every thousand, according to the scale shown at the left. These points are then joined by straight lines and the whole broken line may be called the 'word spectrum' or 'characteristic curve' of the author as derived from the group of words considered. The group of 1,000 words from 'Vanity Fair' enumerated above is thus graphically represented by the continuous line in Fig. 1, and the method of constructing the characteristic curve will be readily understood by comparing this with the numbers given. As a thousand is a very small number in a problem of this kind, the curve representing any single group of that number of words is practically certain to differ more or less from that of any other such group. In Fig. 1 the dotted line represents a group of 1,000 words, immediately following that already referred to. Perhaps the most astonishing thing about these two lines is not that they differ, but that they agree as well as they do. It is really remarkable that any marked peculiarity in the use of words is almost sure to be revealed in this way, even in comparatively small groups. In the two diagrams of Fig. 1 it is interesting to note their general sameness, especially as shown in a tendency to equality of words of six and seven letters and also in words of eleven and twelve letters.

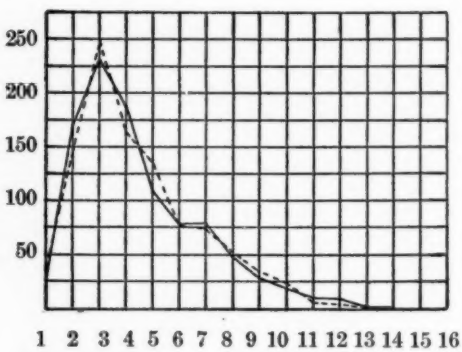


FIG. 1. TWO GROUPS—1000 EACH—VANITY FAIR.

When the number of words in each group is increased there is, of

course, closer agreement of their diagrams, and this became so evident in the earlier stages of the investigation that the conclusion was soon reached that if a diagram be made representing a very large number of words from a given author, it would not differ sensibly from any other diagram representing an equally large number of words from the same author. Such a diagram would then reflect the persistent peculiarities of this author in the use of words of different lengths and might be called the characteristic curve of his composition. Curves similarly formed from anything that he had ever written could not differ materially from this, although curves of other authors might possibly, but would not probably, agree closely with his.

Thus, if this principle were established, the method might be useful as a means of identification of authorship, and it might be relied upon with great confidence to show that a certain author did not write a certain composition.

In the earlier application of the method many interesting facts were brought out, some of which are worth mentioning here, although a full account of the preliminary work was published in 'Science' of March 11, 1887. It was soon discovered that among writers of English the three-letter word occurred much more frequently than any other. Indeed in the earlier investigation only one exception to this rule was found and that was in the writings of John Stuart Mill, who uses two-letter words more often than any other. This was surprising at first, especially in view of the large average word-length of Mill's composition, which is considerably in excess of that of any other author thus far examined, but it is easily explained by the very frequent appearance of prepositional phrases, necessitating the use of such two-letter words as *in, on, to, of,* etc., to an extent unapproached by other writers. Mill's writings furnished an opportunity for comparing the curves representing two different periods of an author's life. A comparison of two groups of 5,000 words each from his 'Political Economy' and his 'Essay on Liberty' showed the presence of the same peculiarities in word choosing, and in every thousand of the ten examined the two-letter word was in excess. No other writer of English has been found to use two-letter words oftener than any other, but it is not at all improbable that there may be such.

Through the interest of Mr. Edward Atkinson, it became possible to give a partial answer to the question, Can an author purposely avoid the peculiarities of style that belong to his normal composition? Mr. Atkinson, having addressed a body of college alumni on a certain topic, afterward gave what he meant to be the same address to a body of workingmen, but in the latter instance he made a special effort to use simple, short words and sentences of the simplest and plainest construction. Although relating to the same topic the two addresses 'read'

very differently, but their diagrams are strikingly alike in their main feature. As a matter of interest 'counts' were made of groups of about 5,000 words each from various languages other than English. The characteristic curves thus derived for Italian, Spanish, French, German, Latin and Greek are shown in Figs. 2 and 3, and, for convenience in comparison, that of Dickens's English is added. Many of these 'counts' were furnished by friends who became interested in the matter, and an incident of no little interest was the receipt of a column of numbers on a strip of paper with nothing to indicate its origin or meaning. Suspecting, however, that it might be a 'word count,' its diagram was constructed and it was instantly and beyond all reasonable doubt identified as coming from the Latin of Cæsar.

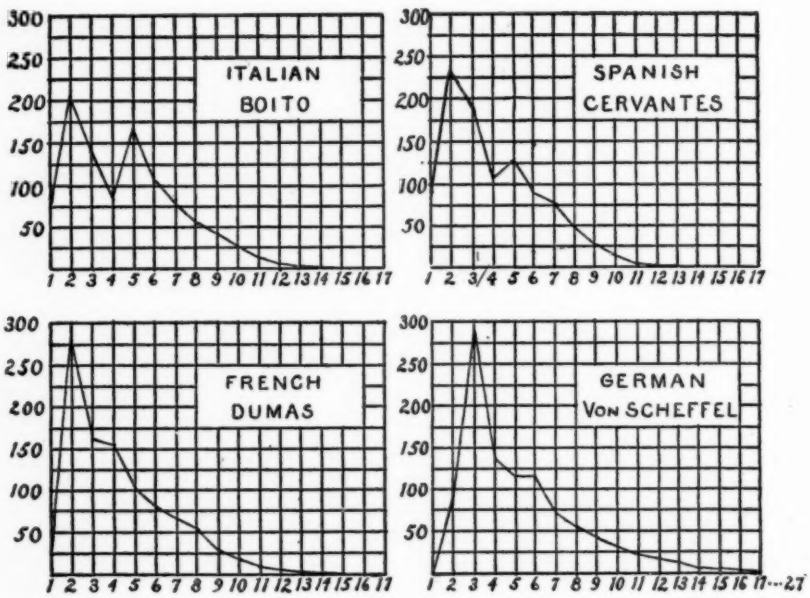


FIG. 2.

The original published description referred to above concludes as follows:

From the examinations thus far made I am convinced that 100,000 words will be necessary and sufficient to furnish the characteristic curve of a writer—that is to say, if a curve is constructed from 100,000 words of a writer, taken from any one of his productions, then a second curve from another 100,000 words would be practically identical with the first and that this curve would, in general, differ from that formed in the same way from another writer, to such an extent that one could always be distinguished from another. To demonstrate the existence of such a curve would require the enumeration of the letters of several hundred thousand words from each of a number of writers. Should its existence be established the method might then be applied to cases

of disputed authorship. If striking differences are found of known and suspected compositions of any writer, the evidence against identity of authorship would be quite conclusive. If the two compositions should produce curves which are practically identical, the proof of a common origin would be less convincing; for it is possible, although not probable, that two writers might show identical characteristic curves.

With this conclusion the matter remained for more than ten years. On innumerable occasions it was suggested that the process ought to be applied to an examination of the writings of Bacon and Shakespeare with a view of forever settling a controversy which will doubtless forever remain unsettled. This, of course, had been all along in view, but it involved an expenditure of time and labor in letter and word counting quite beyond what might be expected from individual en-

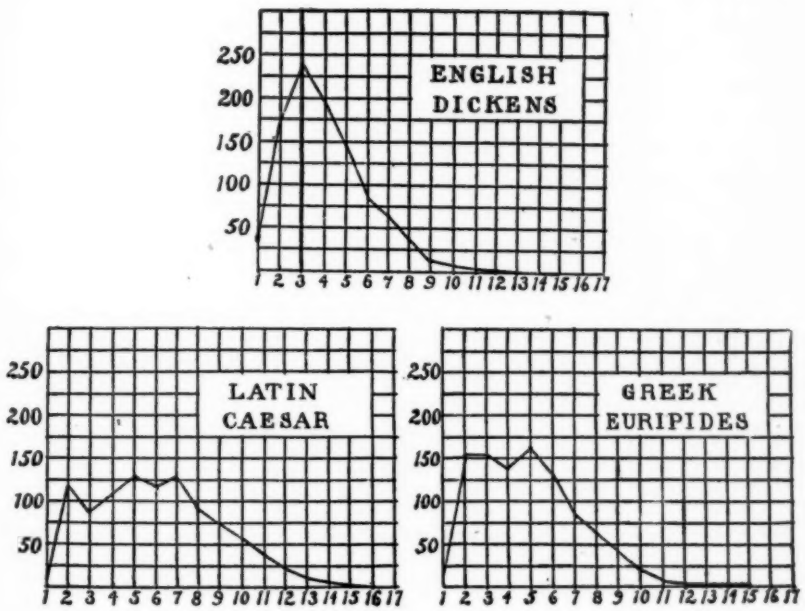


FIG. 3.

thusiasm. The operation is not one of thrilling interest, and volunteer assistance could not be depended upon when the number of things to be counted and classified grew into millions.

That the method has been applied at last to this most curious and yet most interesting question is entirely due to the liberality of Mr. Augustus Heminway, of Boston, who kindly offered to defray the expenses of the work, that is, to employ persons to count and classify nearly two millions of words. Besides expressing my indebtedness to Mr. Heminway, I wish to make grateful acknowledgment of the ex-

cellent and entirely satisfactory manner in which the heavy task of counting was performed by the ladies who undertook it, Mrs. Richard Mitchell and Miss Amy C. Whitman, of Worcester, Massachusetts. Their intelligent interest in the problem itself, together with their excellent knowledge of the various authors under examination and familiarity with the literature of the Shakespearean period, contributed greatly to the easy accomplishment of the work. The operation of counting was greatly facilitated by the construction of a simple counting machine by which a registration of a word of any given number of letters was made by touching a button marked with that number. One of the counters, with book in hand, called off 'five,' 'two,' 'three,' etc., as rapidly as possible, counting the letters in each word carefully and taking the words in their consecutive order, the other registering, as called, by pressing the proper buttons. Practice enabled the counters to do the work with remarkable rapidity, so that, although they were occupied for several months, the total time required was really only about one-quarter of the original estimate. The work was very exhausting, however, and could not be kept up satisfactorily more than three to five hours each day. After some preliminary work the counting of Shakespeare was seriously begun, and the result from the start with the first group of a thousand words was a decided surprise. Two things appeared from the beginning: Shakespeare's vocabulary consisted of words whose average length was a trifle below four letters, less than that of any writer of English before studied; and his word of greatest frequency was the *four-letter* word, a thing never met with before. His preference for the four-letter word may be said, indeed, to constitute the striking characteristic of his composition. At first it was thought that it might be a general characteristic of the English of his time, but that was found to be not the case. Its appearance in the composition of one or two of his contemporaries will be considered presently. Altogether about 400,000 words of Shakespeare were counted and classified, including, in whole or in part, nearly all of his most famous plays. His 'characteristic curve' is most persistent, that based on the first 50,000 words differing very little from that of the whole count. Two groups have been formed by combining alternate small groups (single plays or parts of plays) in a purely mechanical way, so as to include as nearly as may be the same number of words in each. The curves corresponding to them are plotted in Fig. 4, where, however, the differences have been of necessity somewhat exaggerated in order to make them show at all. The practical identity of these curves must be regarded as convincing evidence of the soundness of the original assumption. Not all of the Shakespeare count was completed at one time; other authors were taken up, and it is worth noting that the counters declared their ability to recognize Shakespeare by the mere 'run of words' without

knowing what book or author was in hand, more especially on account of the exceptional excess of four-letter words.

The characteristic curve of Bacon was developed along with that of Shakespeare and was based on his 'Henry VII.,' the 'Advancement of Learning' and a large number of his shorter essays, the total number of words being nearly 200,000.

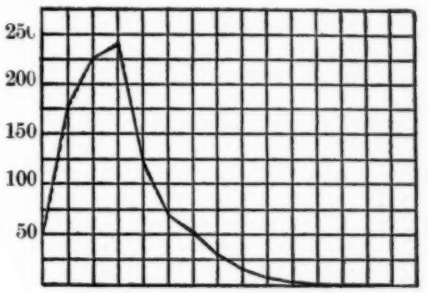


FIG. 4. SHAKESPEARE—TWO GROUPS, ABOUT 200,000 WORDS EACH.

Besides these, extensive counting was done from the writings of Ben Jonson, Addison, Milton, Beaumont and Fletcher, Christopher Marlowe, Goldsmith and Lord Lytton and small groups from a few more modern authors. It is possible, here, to give only general conclusions and to exhibit the diagrams of the more important and interesting results.

One of the first questions likely to be raised is, when an author writes both prose and poetry, will the two styles of composition follow the same general law and show the same characteristic curves? Unfortunately it is not possible to answer this as completely as could be desired, as no one has written enough in two or more different styles, as prose, poetry, history, essay, drama, etc., to produce normal characteristic diagrams. Several of the authors above named were examined with this point in view, and while some of them exhibited somewhat different curves in play writing and in essay or serious prose composition in every case any marked peculiarity found in one style was also found in the other. A good example of this is shown in the two Shakespeare curves of Fig. 5. The continuous line is based on his 'Rape of Lucrece' and 'Venus and Adonis,' while the broken line is his normal curve in play writing.

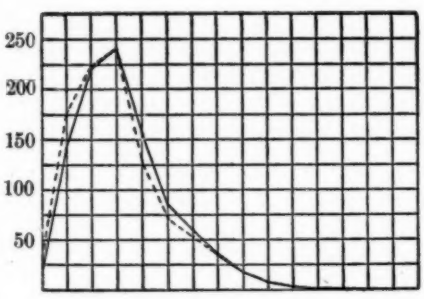


FIG. 5. SHAKESPEARE —— POETRY ..... PROSE.

It will be noted that the Shakespearean peculiarity of an excessive use of four-letter words is shown in the same degree in both and that while there are apparent differences of considerable magnitude the curves are really strikingly alike, every bend in one having a correspond-

ing flexure in the other. This is typical of all comparisons of different styles of composition by the same author. Undoubtedly there will always be found differences in the graphic representations of serious prose compositions and those of a higher vein, poetry or play, by the same writer, but the evidence at hand goes to show that the leading personal peculiarities of composition will invariably be found in both.

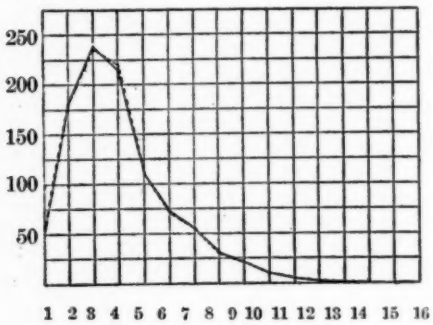


FIG. 6. TWO GROUPS, BEN JONSON.

Fig. 6 shows the curves of two groups of about 75,000 words each from the plays of Ben Jonson, the most notable literary contemporary of Shakespeare. Their close agreement is another very satisfactory confirmation of the fundamental principle and their difference from the Shakespearean curve is striking. It will be observed that Jonson follows the usual practice of making use of the three-letter word most frequently.

Fig. 7 shows the characteristic curves of Bacon and Shakespeare side by side and may be regarded, perhaps, as the objective point of the entire investigation. The reader is at liberty to draw any conclusions he pleases from this diagram.

Should he conclude that, in view of the extraordinary differences in these lines, it is clear that Bacon could not have written the things ordinarily attributed to Shakespeare, he may yet, possibly, be willing to admit that, in Mr. Heminway's own words, 'the question still remains, who did?' Assuming this question to be a reasonable one, the method now under consideration can never do more than direct inquiry or suspicion.

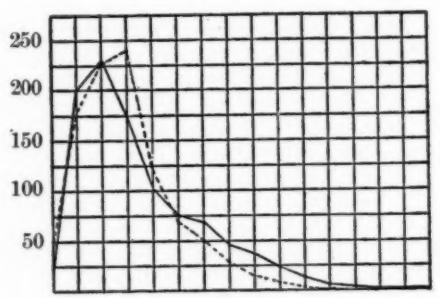


FIG. 7. —— BACON ..... SHAKESPEARE.

During the progress of the count it seemed as if the Shakespearean peculiarity of the excessive use of words of four letters was unique, that no other writer would be found with this characteristic. On working out the results of a very extensive count of the plays of Beaumont and Fletcher, however, it was found that on the final average the num-

ber of four-letter words was slightly greater than that of three letters, although the excess was by no means so persistent in small groups. The curve of their composition is, on the whole, quite like that of Shakespeare. The lack of persistency of form among small groups may be accounted for by the fact that the work is in a large, though unknown, degree a joint product. The comparison with Shakespeare is shown in Fig. 8.

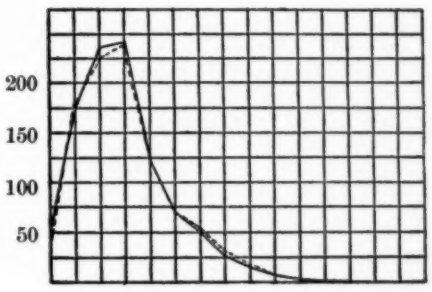


FIG. 8.—— BEAUMONT AND FLETCHER ..... SHAKESPEARE.

It was in the counting and plotting of the plays of Christopher Marlowe, however, that something akin to a sensation was produced among those actually engaged in the work. Here was a man to whom it has always been acknowledged, Shakespeare was deeply indebted; one of whom able critics have declared that he 'might have written the plays of Shakespeare.' Indeed a book has been only recently published to prove that he did write them. Even this did not lessen the interest with which it was discovered that in the characteristic curve of his plays Christopher Marlowe agrees with Shakespeare about as well as Shakespeare agrees with himself, as is shown in Fig. 9. Finally, an interesting incident developed in an examination of a bit of dramatic composition by Professor Shaler, of Harvard University, entitled 'Armada Days.' It was a brochure of only about twenty thousand words, printed for private circulation, in which the author had endeavored to compose in the spirit and style of the Elizabethan Age. Although too small to produce anything like a 'normal' curve it was counted and plotted, and the diagram indicated that Professor Shaler had not only caught the spirit of the literature of the time, but that he had also unconsciously adopted the mechanism which seems to characterize it. In the excess of the four-letter word and in other respects the curve was rather decidedly Shakespearean, although it was written before its author knew anything of such an analysis as this.

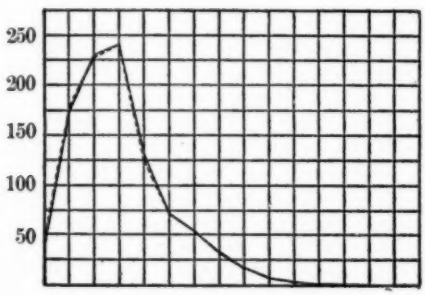


FIG. 9.—— MARLOWE ..... SHAKESPEARE.

THE IMPORTANCE OF GENERAL STATISTICAL IDEAS.*

By Sir ROBERT GIFFEN, K.C.B., LL.D., F.R.S.

I TRUST you will excuse me, on an occasion like the present, for returning to a topic which I have discussed more than once—the utility of common statistics. While we are indebted for much of our statistical knowledge to elaborate special inquiries, such as were made by Mr. Jevons on prices and the currency, or have lately been made by Mr. Booth into the condition of the London poor, we are indebted for other knowledge to continuous official and unofficial records, which keep us posted up to date as to certain facts of current life and business, without which public men and men of business, in the daily concerns of life, would be very much at a loss. What seems to me always most desirable to understand is the importance of some of the ideas to be derived from the most common statistics of the latter kind—the regular records of statistical facts which modern societies have instituted, especially the records of the census, which have now existed for a century in most European countries and among peoples of European origin. Political ideas and speculation are necessarily colored by ideas originating in such records, and political action, internationally and otherwise, would be all the wiser if the records were more carefully observed than they are, and the lessons to be derived widely appreciated and understood.

I propose now to refer briefly to one or two of these ideas which were taken up and discussed on former occasions,† and to illustrate the matter farther by a reference to one or two additional topics suggested in the same manner, and more particularly by the results of the last census investigations, which complete in this respect the record of what may be called the statistical century *par excellence*—the century which has just closed.

Increase of European Population during last Century.

The first broad fact then of this kind, which I have discussed on former occasions, is the enormous increase of the population of Eu-

* Address of the President to the Economic Science and Statistics Section of the British Association for the Advancement of Science. Glasgow, 1901.

† Cf. *Essays in Finance*, 2nd series, pp. 275–364, and *Proceedings of Manchester Statistical Society*, October 17, 1900.

ropean countries and of peoples of European origin during the century just passed, especially the increase of the English people and of the United States, along with the comparative stationariness of the population of one or two of the countries, particularly France, at the same time. The growth all round is from about 170 millions at the beginning of the century to about 510 millions (excluding South American countries and Mexico); while the growth of the United States alone is from a little over 5 to nearly 80 millions, and of the English population of the British Empire from about 15 to 55 millions. Germany and Russia also show remarkable growth, from 20 to 55 millions in the one case and from 40 to 135 millions in the other—partly due to annexation; but the growth of France is no more than from 25 to 40 millions. Without discussing it, we may understand that the economic growth is equally if not more remarkable. The effect necessarily is to assure the preponderance of European peoples among the races of the world—to put aside completely, for instance, the nightmares of yellow or black perils arising from the supposed overwhelming mass of yellow or black races, these races by comparison being stationary or nearly so. The increase of population being continuous, unless some startling change occurs before long, each year only makes European preponderance more secure. Equally it follows that the relative position of the English Empire, the United States, Russia and Germany has become such as to make them exclusively the great world powers, although France, for economic reasons, notwithstanding the stationariness of its population, may still be classed amongst them. When one thinks what international politics were only a hundred years ago—how supreme France then appeared; how important were Austria, Italy, Spain, and even countries like Holland, Denmark and Sweden—we may surely recognize that with a comparatively new United States on the stage, and with powers like Russia and Germany come to the front, the world is all changed politically as well as economically, and that new passions and new rivalries have to be considered.

The figures also suggest that for some time at least the movements going on must accentuate the change that has occurred. According to the latest figures, there is no sign that either in France or any other European country which has been comparatively stationary has any growth of population commenced which will reverse the change, while a large increase of population goes on in the leading countries named. This increase, it is alleged, is going on at a diminishing rate—a point to be discussed afterwards—but in the next generation or two there is practically no doubt that the United States will be a larger international factor than it is, both absolutely and relatively, and that Russia, Germany and the English people of the British Empire will also grow, though not in such a way, apparently, as to prevent the greater relative

growth of the United States, and notwithstanding perhaps some relative changes of a minor character amongst themselves.

The foreign nations then with which the British Empire is likely to be concerned in the near future are Russia, Germany and the United States; and other Powers, even France, must more and more occupy a second place, although France, for the moment, partly in consequence of its relations with Russia, occupies a special place.

Special Position of British Empire.

Another idea which follows from a consideration of the same facts is the necessity laid upon the British Empire to consolidate and organize itself in view of the large additions of subject races made to it in the last century, and especially in the last twenty years of the century. In a paper which I read before the Royal Colonial Institute two years ago, an attempt was made to show that the burden imposed on the white races of the Empire by these recent acquisitions was not excessive as far as the prospect of internal tumults was concerned. Relatively to some other Powers, especially France, we have also been gaining intentionally in strength and resources. But whether we had gained internationally on the whole, looking at the growth of powers like Russia, the United States and Germany, and their greater activity in world-politics, was a different question. The problem thus stated remains. It would be foreign to the scope of an address like this, which must avoid actual politics, to examine how far light has been thrown on it by the South African war. No one can question at least that the organization of the Empire must be governed by considerations which the international statistics suggest, and that no step can be taken safely and properly unless our public men fully appreciate the ideas of international strength and resources as well as other considerations which are germane to the subject.

Europe and Foreign Food Supplies.

Another idea to which attention may be drawn appears to be the increasing dependence of European nations upon supplies of food and raw material obtained from abroad. We are familiar with a conception of this kind as regards the United Kingdom. For years past we have drawn increasing supplies from abroad, not merely in proportion to the growth of population, but in larger proportion. The position here obviously is that, with the industries of agriculture and the extraction of raw material (except as regards the one article, coal) practically incapable of expansion, and with a population which not only increases in numbers, but which becomes year by year increasingly richer per head, the consuming power of the population increases with enormous

rapidity, and must be satisfied, if at all, by foreign imports of food and raw materials; there is no other means of satisfaction. But what is true of the United Kingdom is true in a greater or less degree of certain European countries—France, the Low Countries, the Scandinavian countries, Austria-Hungary, Italy and Germany. Especially is it true in a remarkable degree of Germany, which is becoming increasingly industrial and manufacturing, and where the room for expansion in agriculture is now very limited. Those interested in the subject may be referred to an excellent paper by Mr. Crawford, read at the Royal Statistical Society of London about two years ago. What I am now desirous to point out is the governing nature of the idea, which necessarily follows from the conception of a European population living on a limited area, with the agricultural and extractive possibilities long since nearly exhausted, and the population all the time increasing in numbers and wealth. Such a population must import more and more year by year, and must be increasingly dependent on foreign supplies.

I shall not attempt to do over again what is done in Mr. Crawford's paper, but a few figures may serve to illustrate what is meant. In the 'Statistical Abstract' for the principal and other foreign countries I find tables for certain European countries classifying the imports for a series of years into articles of food, raw and semi-manufactured articles, etc. From these I extract the following particulars for all the countries which have tables in this form:

Imports of Articles of Food and Raw Materials and Semi-manufactured Articles into the undermentioned Countries in 1888 *and* 1898 *compared.*

	1888	1898	Increase.	
			Amount.	Per Cent.
Articles of Food, etc.				
Russia.....1,000 roubles	78;975	105,391	27,416	35
German Empire, mln. marks	907	1,819	912	100
France.....1,000 francs	1,503,000	1,505,000	Nil	Nil
Switzerland ... "	238,000	332,000	94,000	40
Italy .....1,000 lire	274,480	391,600	117,120	42
Austria-Hungary, 1,000 gulden	(1891) 108,441	191,919	92,478	85
Raw and Semi-manufactured Materials.				
Russia.....1,000 roubles	241,497	313,629	71,132	29
German Empire, mln. marks	1,507	2,247	740	49
France.....1,000 francs	2,014	2,348	334	16
Switzerland ... "	308,110	390,111	82,001	27
Italy .....1,000 lire	398,330	509,418	111,088	28
Austria-Hungary, 1,000 gulden	231,000	293,000	62,000	27

The drawback to this table is that it is one of values. Consequently the increase of values in the later years may in part be one of values only without corresponding increase of quantities. But the general course of prices in the period in question was not such as to cause a great change of values apart from a change in quantities. The inference seems undeniable, then, that the Continental countries named, especially Germany, have largely increased their imports of food and raw materials of recent years—that is, have become increasingly dependent on foreign and over-sea supplies. The position of Germany, with its enormous increase of food imports—from 907 to 1,819 million Marks, or from 45 to over 90 million sterling, and its corresponding increase of raw material imports—from 1,507 to 2,247 million Marks, or from 75 to 112 million sterling—is especially remarkable.

An examination in detail of the quantities imported of particular articles would fully confirm the impression given by the summary figures. But it may be enough to refer to the 'Statistical Abstract' from which I have been quoting, as well as to Mr. Crawford's paper. The figures are not out of the way in any respect, and it is the idea we have now to get hold of.

The inference is that the difference between the United Kingdom and Continental countries, especially Germany, as regards dependence on foreign supplies of food and raw materials, is only one of degree, and that as regards Germany at least, the conditions are already remarkably like those of the United Kingdom, while the more rapidly Germany increases its manufacturing and industrial population, the more like it will become to this country. In other words, in the future there will be two great countries, and not one only, dependent largely for their food and raw materials on supplies from abroad. What their position is to be economically and otherwise relatively to the United States, which is at once the main source of supply and a competitor with European countries in manufactures, is obviously a matter of no little interest. As a believer in free trade, I am sure that nothing but good will come to all the countries concerned if trade is interfered with as little as possible by tariffs and government regulations. I believe, moreover, that the practice of free trade, whatever their theories may be, will unavoidably be accepted by all three countries before long. Obviously, however, as the new tariff in Germany indicates, there is to be a great struggle in that country before the situation is accepted; and if some people in this country had their way, notwithstanding our long experience of free trade and its blessings, we should even have a struggle here.

There is another point of view from which the facts should be studied. We are accustomed, and rightly so, I think, to consider naval

preponderance indispensable to the safety of the Empire, and especially indispensable to the safety of the country from blockade, and from the interruption of its commerce, which would be our ruin. But our position in this respect is apparently not quite exceptional. Less or more our Continental neighbors, and especially Germany, are in the same boat. In the event of war, if they could not make up the loss by traffic over their land frontiers, they would be just as liable to suffer from blockade and interrupted commerce as we are. It is conceivable, moreover, that in certain wars some of the countries might not be able to make up by traffic over their land frontiers for blockade or interruption of commerce by sea. We may apprehend, for instance, that Germany, if it were victorious by sea in a war with France, would insist upon Belgium and Holland on one side, and Italy and Spain on the other side, not supplying by land to France what had been cut off by sea. One or more of these countries might be allies with Germany from the first. Contrariwise France and Russia, if at war with Germany and the Triple Alliance, might practically seal up Germany if they were successful at sea, insisting that the Scandinavian countries and Holland should not make up to Germany by land what had been cut off by sea. Germany in this view, apart from any possibility of rupture with this country, has a case for a powerful fleet. It is not quite so much liable to a blockade as we are, but there is a liability of the same kind. The question of naval preponderance among rival powers may thus become rather a serious one. If preponderance is to be nearly as essential to Germany as it is to this country, who is to preponderate? What our practical action ought to be in the premises is a question that might easily lead us too far on an occasion like this, but the facts should be ever present to the minds of our public men. We may be quite certain that they are quite well known and understood in the councils of the Russian, German, French and other Continental Governments.

New Population and New Markets.

Another idea suggested by the facts appears to be an answer to the question as to how new markets are to be found for the products of an increasing population—a question which vexes the mind of many who see in nothing but foreign trade an outlet for new energies. The point was mentioned in my address at Manchester a year ago, but it deserves, perhaps, a more elaborate treatment than it was possible then to give it. What we see then is that not only in this country, but in Germany and other Continental countries, millions of new people are, in fact, provided for in every ten years, although the resources of the country in food and raw materials are generally used to the full extent, and not capable of farther expansion, so that increasing supplies of food and

raw material have to be imported from abroad. How is the thing done? Obviously the main provision for the wants of the new people is effected by themselves. They exchange services with each other, and so procure the major part of the comforts and luxuries of life which they require. The butcher, the baker, the tailor, the dressmaker, the milliner, the shoemaker, the builder, the teacher, the doctor, the lawyer, and so on, are all working for each other the most part of their lives, and the proportion of exchanges with foreign countries necessary to procure some things required in the general economy may be very small. These exchanges may also very largely take the form of a remittance of goods by foreign countries in payment of interest on debts which they owe, so that the communities in question obtain much of what they want from abroad by levying a kind of rent or annuity which the foreigner has to pay. If more is required, it may be obtained by special means, as, for instance, by the working of coal for export, which gives employment in this country to about 200,000 miners, by the employment of shipping in the carrying trade, by the manufacture of special lines of goods, and so on. But the main exchanges of any country are, and must be, as a rule, at home, and the foreign trade, however important, will always remain within limits, and bearing some proportion to the total exchanges of the country. Hence, when additions to the population, and how they are to live, are considered, the answer is that the additions will fill up proportionately the framework of the various industries already in existence, or the ever-changing new industries for home consumption which are always starting into being. These are the primary outlets for new population even in old countries like the United Kingdom and Germany. Of course, active traders and manufacturers, each in their own way, are not to take things for granted. They must strive to spread their activities over foreign as well as over home markets. But looking at the matter from the outside, and scientifically, it is the home and not the foreign market which is always the more important.

The same may be said of a country in a somewhat different economic condition from England and Germany, viz., the United States. I can only refer to it, however, in passing, as the facts here are not so clearly on the surface. Contrary to England and Germany, which have no food resources and resources of raw material capable of indefinite expansion, the United States is still to a large extent a virgin country. Its increasing population is therefore provided for in a different way for the most part from the increase in England and Germany. But even in the United States it has been noticeable at each of the last census returns that the increasing population finds an outlet more and more largely, not in agriculture and the extraction of raw materials, but in the miscellaneous pursuits of industry and manufacture. The town population

increases disproportionately. In the last census especially it was found that the overflow of population over the far Western States seemed to have been checked, the increase of population being mainly in the older States and the towns and cities of the older States. The phenomena in England and Germany and in other Continental countries are accordingly not singular. The older countries, and the older parts even of a new country like the United States are becoming more and more the centers where populations live and grow, because they are the most convenient places for the general exchange of services with each other among the component parts of a large population, which constitutes production and consumption. A small expenditure of effort in proportion enables such communities to obtain from a distance the food and raw materials which they require. Migration is no longer the necessity that it was.

Decline in Rate of Growth of Population.

I come now to another idea appearing on the surface of the census returns when they are compared for a long time past, and the connected returns of births, marriages and deaths, which have now been kept in most civilized communities for generations. Great as the increase of population is with which we have been dealing, there are indications that the rate of growth in the most recent census periods is less in many quarters than it formerly was, while there has been a corresponding decline in the birth-rates; and to some extent, though not to the same extent, in the rate of the excess of births over deaths, which is the critical rate of course in a question of the increase of population. These facts have suggested to some a question as to how far the increase of population which has been so marked in the past century is likely to continue, and speculations have been indulged in as to whether there is a real decline in the fecundity of population among the peoples in question resembling the decline in France, both in its nature and consequences. I do not propose to discuss all these various questions, but rather to indicate the way in which the problem is suggested by the statistics, and the importance of the questions thus raised for discussion, as a proof of the value of the continuous statistical records themselves.

The United States naturally claims first attention in a matter like this, both on account of the magnitude of the increase of population there, and the evidence that recent growth has not been quite the same as it was earlier in the century. Continuing a table which was printed in my address as president of the Statistical Society, in 1882, above referred to, we find that the growth of population in the United States since 1800 has been as follows in each census period:

Population in the United States, and Increase in each Census Period of the Nineteenth Century.

Year.	Population.	Increase since Previous Census.	
		Amount.	Per Cent.
	Millions.	Millions.	
1800	5.3	—	—
1810	7.2	1.9	36
1820	9.6	2.4	33
1830	12.9	3.3	34
1840	17.1	4.2	33
1850	23.2	6.1	36
1860	31.4	8.2	36
1870	38.5	7.1	23
1880	50.1	11.6	30
1890	62.6	12.5	25
1900	75.7*	13.1	21

Thus it is quite plain that something has happened in the United States to diminish the rate of increase of population after 1860. Up to that time the growth in each census period from 1800 downwards had ranged between 33 and 36 per cent. Since then the highest rates have been 30 per cent. between 1870 and 1880 and 25 per cent. between 1880 and 1890. There is a suspicion, moreover, that, owing to errors in the census of 1870, which were corrected in 1880, the increase between 1870 and 1880 was not quite so high as stated. There is accordingly a somewhat steep decline from a growth in each ten years prior to 1860, ranging between 33 and 36 per cent., to a growth first of about 25 per cent., and finally of 21 per cent. only. The Civil War of the early sixties naturally occurs to one as the explanation of the break immediately after 1860, but the effects could hardly have continued to the present time, and a more general explanation is suggested.

Other special explanations have occurred to me as partly accounting for the change. One is that, prior to 1860, the United States at different times increased its territory and population partly by purchase and partly by annexation. But I cannot make out that either the purchase of Louisiana early in the century, or the subsequent annexations following the Mexican war, would make a material difference. There is a considerable increase certainly after the Mexican war, but it would be difficult indeed to estimate how much of the population of Texas and New Mexico, which was then added to the Union, had previously swarmed over from the Union, and had thus been from the first economically, if not politically, part of the United States. Another obvious suggestion is that possibly immigration into the United States

* This does not include population of Indian reservation, etc., now included in the official census for the first time.

has fallen off as compared with what it formerly was. But this explanation also fails, as far as the official figures carry us. The proportion of immigration to the total increase of population in each census period since 1820, previous to which I have not been able to obtain figures, has been as follows:

Proportion of Immigration to Total Increase of Population in the undermentioned Periods in the United States.

	Per Cent.		Per Cent.
1820–30	4.7	1860–70	35.0
1830–40	14.2	1870–80	24.2
1840–50	27.9	1880–90	42.1
1850–60	31.5	1890–1900	29.4

Immigration, according to these figures, has thus in late years played as important a part as it formerly did in the increase of population in the United States. Possibly the official figures of immigration of late years are a little exaggerated, as the United States Government does not show a balance between immigration and emigration; but whatever corrections may be made on this account, the recent figures of immigration are too large to permit the supposition that the failure of immigrants accounts in the main for the diminished rate of increase of the population generally. The ten years' percentage of increase without immigrants, I may say, varied before 1860 between 24 and 32 per cent., and has since fallen to 14 and 15 per cent. Even if the latter figures should be increased a little to allow for the overestimate of immigration, the change would be enormous.

Passing from the United States, we meet with similar phenomena in Australasia. Indeed, what has happened in Australasia of late has been attracting a good deal of attention. The following short table, which is extracted from the statistics of Mr. Coghlan, the able statistician of the Government of New South Wales, gives an idea of what has occurred:

Population of Australasia at different Dates, with the Annual Increase Per Cent. in each Period.

	Population.	Annual Increase Per Cent. since Previous Date.		Population.	Annual Increase Per Cent. since Previous Date.
	Thousands.			Thousands.	
1788	1.0	—	1851	430.6	7.36
1801	6.5	15.13	1861	1,253.0	11.30
1811	11.5	11.94	1871	1,924.8	4.39
1821	35.6	5.88	1881	2,742.5	3.60
1831	79.3	8.34	1891	3,809.9	3.34
1841	211.1	10.28	1899	4,483.0	2.1

Supplementary Table of Rate per Cent. of Increase since 1890.

	Per Cent.		Per Cent.
1891	3.34	1896	1.84
1892	2.10	1897	1.86
1893	1.96	1898	1.40
1894	1.95	1899	1.44
1895	1.88		

The decline in the rate of increase is so great and palpable as to need no comment.

Here the perturbations due to immigration have obviously been greater than in the case of the United States. The country was, in fact, settled mainly between 1850 and 1870, without previously having had a population to speak of. But deducting immigration, the increase would appear to have been as follows in each decade:

Rate of Increase Per Cent. of Population in Australasia, deducting Immigration, in the undermentioned Periods.

	Per Cent.		Per Cent.
1851–60	48.5	1880–90	24.5
1860–70	30.0	1890–99	16.0
1870–80	25.0		

Of course, so long as immigration continues, the effect is to swell indirectly the natural increase of population, so that the large increases here shown between 1851 and 1870, and even down to 1890, may be accounted for in part as the indirect result of the large immigration that was going on. But whatever the cause, the fact is unmistakable that the rate of increase, apart from the direct immigration, has declined just as it has done in the United States.

There has been a similar though not nearly so marked a decrease in England, at any rate if we carry the comparison back to the period before 1850. The population at each census period since 1800 in England, with the percentage increase between each census period, has been as follows:

Population of England at the Date of each Census since 1800 *with Percentage of Increase between each Census.*

Year.	Population.	Increase Per Cent. Since Previous Census.	Year.	Population.	Increase Per Cent. Since Previous Census.
	Millions.			Millions.	
1800	8.9	—	1860	20.1	11.9
1810	10.2	14.0	1870	22.7	13.2
1820	12.0	18.1	1880	26.0	14.4
1830	13.9	15.8	1890	29.0	11.6
1840	15.9	14.5	1900	32.3	12.2
1850	17.9	12.9			

Thus the increase between recent census periods has been sensibly less than it was before 1850; and the slight recovery between 1860 and 1880 has not been maintained. We are thus in presence of much the same kind of change as has been shown in the United States and in Australasia.

It should be noted, however, in order that we may not strain any fact, that, when the United Kingdom is viewed as a whole, Scotland

and Ireland, as well as the senior partner, being taken into account, it cannot be said that there is any falling off in the rate of growth of the population since 1850. For several decades after that, in fact, the rate of growth of the United Kingdom as a whole was diminished enormously by the emigration from Ireland, and the growth since 1860 has been at a greater rate than in the thirty years before. There may be new causes at work which will again diminish the rate of growth, but in a broad view they do not make themselves visible owing to the disturbance caused by the Irish emigration. Still the facts as to the United Kingdom as a whole ought not to prevent us from considering the facts respecting England only along with the similar facts respecting the United States and Australasia.

These diminutions in the rate of growth of large populations, as I have indicated, are corroborated by a study of the birth-rates, and of the rate of the excess of births over deaths.

The United States unfortunately is without birth- or death-rates, owing to the want of a general system of registration over the whole country. This is a most serious defect in the statistical arrangements of that great country, which it may be hoped will be remedied in time. In the absence of the necessary records I have made some calculations so as to obtain a figure which may be provisionally substituted for a proper rate of the excess of births over deaths, which I submit for what it may be worth as an approximation, and an approximation only. In these calculations one-tenth of the increase of population between two census periods, apart from immigration, is compared with the mean of the population at the two census dates themselves, with the following results:

Approximate Rate of Excess of Births over Deaths in the United States, calculated from a Comparison of One-tenth the Increase of Population between the Census Periods, deducting Immigrants, with the Mean of the Numbers of the Population at the two Census Dates.

Year.	1 Population.	2 Mean of Population Between Two Censuses.	3 One-tenth of Increase Since Previous Census, Less Immigrants.	4 Calculated Excess of Births Over Deaths per 1,000, Proportion of Col. 3 to Col. 2.
	Millions.	Millions.	Thousands.	
1800.....	5.3	—	—	—
1810.....	7.2	6.2	—	—
1820.....	9.6	8.4	—	—
1830.....	12.9	11.2	308	28
1840.....	17.1	15.0	360	24
1850.....	23.2	20.1	441	22
1860.....	31.4	27.3	565	21
1870.....	38.5	35.0	462	13
1880.....	50.2	44.4	878	20
1890.....	62.6	56.4	722	13
1900.....	75.7	69.2	923	13

Thus, while the excess rate was as high as 21 to 28 per 1,000 before 1860, it has since fallen to one of 13 only, or about one-half. Whatever validity may attach to the method of calculation, the real facts would no doubt show a change in the direction of the table—a decline in the rate of the excess of births over deaths from period to period. The decline in the growth of population is thus not merely the direct effect of a change in immigration, but is connected with the birth- and death-rates themselves, although these rates are of course indirectly affected by the amount and proportion of immigration. It would be most important to know what the decline in the birth-rate is by itself, and how far its effects on the growth of population have been mitigated or intensified by changes in the death-rate; but United States records generally give no help on this head.

Dealing with Australasia in the same way, we have the advantage of a direct comparison of both birth- and death-rates and the rate of the excess of births over deaths. This is done in the following table:

Birth-rate and Death-rate and Rate of Excess of Births over Deaths in Australasia for undermentioned Years.

[From Mr. Coghlan's Statistics.]

	Birth-rate.	Death-rate.	Excess of Births Over Deaths.
1861–65	41.92	16.75	25.17
1866–70	39.84	15.62	24.22
1871–75	37.34	15.26	22.08
1876–80	36.38	15.04	21.34
1881–85	35.21	14.79	20.42
1886–90	34.43	13.95	20.48
1891–95	31.52	12.74	18.78
1896–99	27.35	12.39	14.96

Thus from a high birth-rate forty years ago Australasia has certainly gone down to very ordinary birth-rates, lower than in the United Kingdom and in Continental countries, and Australasia certainly has had heavy declines in the rate of excess of births over deaths, viz., from 25.17 in 1861–65 to 15 in 1896–99, which is to be compared with the decline in the United States, as above stated approximately, from 28 in 1820–30, and 21 as late as 1860, to 13 in the last twenty years.

A similar table for England only gives the following results:

Birth-rate and Death-rate and Rate of Excess of Births over Deaths in England for undermentioned Years.

	Birth-rate per 1,000.	Death-rate per 1,000.	Excess of Birth-rate Over Death-rate.
1851	34.2	22.0	12.2
1861	34.6	21.6	13.0
1871	35.0	22.6	12.4
1881	33.9	18.9	15.0
1891	31.4	20.2	11.2
1899	29.3	18.3	11.0

Note.—Highest birth-rate in 1876, 36.3.

Here the birth-rates, to begin with, are not so high as in Australasia, and presumably in the United States, and the excess of births over deaths, though it has declined a good deal since 1871–81, when it was highest, has been by comparison fairly well maintained, being still 11 per 1,000, as compared with 12.2 in 1851.

We have thus on one side a manifest decline in the rate of growth of population in three large groups of population, coupled with a large decline of birth-rates in England and Australasia where the facts are known, and a smaller decline in the rate of the excess of births over deaths, this decline in England as yet being comparatively small. Such facts cannot but excite inquiry, and it is an excellent result of the use of continuous statistical records that the questions involved can be so definitely raised.

As I have stated, it would be foreign to the object of this paper to discuss fully the various questions thus brought up for discussion, but one or two observations may be made having regard to some inferences which are somewhat hastily drawn.

1. The rate of growth of population of the communities may still be very considerable, even if it is no higher than it has been in the last few years. A growth of 16, 15, or even 12 per cent. in ten years, owing to the excess of births over deaths, is a very considerable growth, though it is much less than the larger figures which existed in some parts forty or fifty years ago. What has happened in the United Kingdom is well worth observing in this connection. Since 1840 the population of the United Kingdom as a whole has increased nearly 60 per cent., although the increase in most of the decades hardly ever exceeded 8 per cent., and in 1840–50 was no more than 2½ per cent. The increase, it must be remembered, goes on at a compound ratio, and in a few decades an enormous change is apparent. The increase from about 170 to 510 millions in the course of the last century among European people generally, though it includes the enormous growth of the United States in those decades, when the rate of growth was at the highest, also includes the slower growth of other periods, and the slower growths of other countries. An addition of even 10 per cent. only as the average every ten years would far more than double the 500 millions in a century, and an increase to at least 1,500 millions during the century now beginning, unless some great change should occur, would accordingly appear not improbable.

2. Some of the rates of growth of population from which there has been a falling off of late years were obviously quite abnormal. I refer especially to the growth in Australasia between 1850 and 1880, and the growth in the United States prior to 1860. They were largely due to the indirect effect of immigration which has been already referred to.

The population to which immigrants are largely added in a few

years, owing to the composition of the population, has its birth-rates momentarily increased and its death-rates diminished—the birth-rates because there are more people relatively at the child-producing ages, and the death-rates because the whole population is younger, than in older countries. It appears quite unnecessary to elaborate this point. The rates of the excess of births over deaths in a country which is receiving a large immigration must be quite abnormal compared with a country in a more normal condition, while a country from which there is a large emigration, such as Ireland, must tend to show a lower excess than is consistent with a normal condition. This explanation, it may be said, does not apply to England, since it is a country which has not been receiving a large immigration or sending out, except occasionally, a large emigration. England, however, must have been affected both ways by movements of this character. It received undoubtedly a large Irish immigration in the early part of last century, and in more recent periods the emigration in some decades, particularly between 1880 and 1890, appears to have been large enough to have a sensible effect on both the birth-rate and the rate of the excess of births over deaths. This effect would be continued down into the following decade, and the consideration is therefore one to be taken note of as accounting in part for the recent decline in birth-rates in England.

In addition, however, it is not improbable that there was an abnormal increase of population in the early part of last century, due to the sudden multiplication of resources for the benefit of a poor population which had previously tended to grow at a very rapid rate, and would have grown at that rate but for the checks of war, pestilence and famine, on which Malthus enlarges. The sudden withdrawal of the checks in this view would thus be the immediate cause of the singularly rapid growth of population in the early part of last century. It is quite in accordance with this fact that a generation or two of prosperity, raising the scale of living, would diminish the rate of growth as compared with this abnormal development, without affecting in any degree the permanent reproductive energy of the people.

3. It is also obvious that one explanation of the decline in birth-rate, and of the rate of the excess of births over deaths, may also be the greater vitality of the populations concerned, so that the composition of the population is altered by an increase of the relative numbers of people not in the prime of life, so altering the proportion of the people at the child-producing ages to the total. This would be too complex a subject for me to treat in the course of a discursive address. Nor would it explain the whole facts, which include, for instance, an almost stationary annual number of births in the United Kingdom for more than ten years past, notwithstanding the largely increased population. But the case may be one where a great many partial explanations contribute

to elucidate the phenomena, so that this particular explanation cannot be overlooked.

4. There remains, however, the question which many people have rushed in to discuss—viz., whether the reproductive power of the populations in question is quite as great as it was fifty or sixty years ago. We have already heard in some quarters, not merely that the reproductive energy has diminished, but suggestions that the populations in question are following the example of the French, where the rate of increase of the population has almost come to an end. Apart, however, from the suggestions above made as to the abnormality of the increase fifty or sixty years ago, so that some decline now is rather to be expected than not, I would point out that the subject is about as full of pitfalls as any statistical problem can be, for the simple reason that it can only be approached indirectly, as there have been no statistical records over a long series of years showing the proportion of births to married women at the child-producing ages, distinguishing the ages, and showing at the same time the proportion of the married women to the total at those ages. Unless there are some such statistics, direct comparisons are impossible, and a good many of the indirect methods of approaching the subject which I have studied a little appear, to say the least, to leave much to be desired. We find, for instance, that a comparison has been made in Australasia between the number of marriages in a given year or years and the number of births in the five or six years following, which show, it is said, a remarkable decline in the proportion of births to marriages in recent years as compared with twenty or thirty years ago. It is forgotten, however, that at the earlier dates in Australasia, when a large immigration was taking place, a good many of the children born were the children of parents who had been married before they entered the country, while there are hardly any children of such parents at a time when immigration has almost ceased. The answer to such questions is in truth not to be rushed, and the question with statisticians should rather be how the statistics are to be improved in future, so that, although the past cannot be fully explained, the regular statistics themselves will in future give a ready answer.

5. One more remark may, perhaps, be allowed to me on account of the delicacy and interest of the subject. To a certain extent the causes of a decline in reproductive energy may be part and parcel of the improved condition of the population, which leads in turn to an increase of the age at marriage, and an increase of celibacy generally through the indisposition of individual members of the community to run any risk of sinking in the scale of living which they may run by premature marriage. These causes, however, may operate to a great extent upon the birth-rate itself without diminishing the growth of

population, because the children, though born in smaller proportion, are better cared for, and the rate of excess of births over deaths consequently remains considerable, although the birth-rate itself is low. The serious fact would be a decline of the rate of the excess of births over deaths through the death-rate remaining comparatively high while the birth-rate falls. It is in this conjunction that the gravity of the stationariness of population in France appears to lie. While the birth-rate in France is undoubtedly a low one, 21.9 per 1,000 in 1899, according to the latest figures before me, still this would have been quite sufficient to ensure a considerable excess rate of births over deaths, and a considerable increase of population every ten years if the death-rate had been as low as in the United Kingdom—viz., 18.3 per 1,000. A difference of 3.6 per 1,000 upon a population of about 40 millions comes to about 150,000 per annum, or 1,500,000 and rather more every ten years. In France, however, the death-rate was 21.1 per 1,000, instead of 18.3, as in the United Kingdom, and it is this comparatively high death-rate which really makes the population stationary. The speculations indulged in some quarters, therefore, though they may be justified in future, are hardly yet justified by the general statistical facts. The subject is one of profound interest, and must be carefully studied; but the conclusions I have referred to must be regarded as premature until the study has been made.

Conclusion.

Such are a few illustrations of the importance of the ideas which are suggested by the most common statistics—those of the regular records which civilized societies have instituted. It is, indeed, self-evident how important it is to know such facts as the growing weight of countries of European civilization in comparison with others; the relative growth of the British Empire, Russia, Germany and the United States, in comparison with other nations of Europe or of European origin; the dependence of other European countries as well as the United Kingdom upon imports of food and raw materials; the ability of old countries and of old centers in new countries to maintain large and increasing populations; and the evidence which is now accumulating of changes in the rate of growth of European nations, with suggestions as to the causes of the changes. It would be easy, indeed, to write whole chapters on some of the topics instead of making a remark or two only to bring out their value a little. It would also be very easy to add to the list. There was a strong temptation to include in it a reference to the relative growth of England, Scotland and Ireland, which has now become the text of so much discussion regarding the practical question of diminishing the relative representation of Ireland in Parliament, and increasing that of England and Scotland.

It is expedient, however, in an address like this, to avoid anything which verges on party politics, and I shall only notice that while the topic has lately become of keen interest to politicians, it is not new to statisticians, who were able long ago to foresee what is now so much remarked on. This very topic was discussed at length in the addresses of 1882–83, to which reference has been made, and even before that in 1876 it received attention.* Another topic which might have been added is that of the economic growth of the different countries which was discussed in the address in 1883; and such topics as the increase of population in a country like India under the peace imposed by its European conquerors, by which the stationariness of the country in numbers and wealth under purely native conditions has been changed, and something like European progress has been begun. Enough has been said, however, it may be hoped, to justify this mode of looking at statistics, and the ideas suggested by them.

May I once more, then, express the hope, as I have done on former occasions, that as time goes on more and more attention will be given to these common statistics and the ideas derived from them? The domination of the ideas suggested by these common figures of population statistics, in international politics and in social and economic relations, is obvious; and although the decline in the rate of growth of population in recent years, the last of the topics now touched on, suggests a great many points which the statistics themselves are as yet unfit to solve—what *can* be done with a great country like the United States, absolutely devoid of bare records of births, marriages and deaths?—still the facts of the decline as far as recorded throw a great deal of light on the social and economic history of the past century, prepare the way for discussing the further topics which require a more elaborate treatment, and enforce the necessity for more and better records. We may emphasize the appeal then, for the better statistical and economic education of our public men, and for the more careful study by all concerned of such familiar publications as the 'Statistical Abstracts,' the 'Statesman's Year-book,' and the like. The material transformations which are going on throughout the world can be substantially followed without any difficulty in such publications by those who have eyes to see; and to follow such transformations, so as to be ready for the practical questions constantly raised, is at least one of the main uses of statistical knowledge.

* See *Essays in Finance*, 2nd series, p. 290 *et seq.*; p. 330 *et seq.*; and 1st series, p. 280 *et seq.*

THE AIMS OF THE NATIONAL PHYSICAL LABORATORY OF GREAT BRITAIN.*

By R. T. GLAZEBROOK, F.R.S.,

DIRECTOR OF THE NATIONAL PHYSICAL LABORATORY.

A SPEAKER who is privileged to deliver an experimental lecture from this place is usually able to announce some brilliant discovery of his own, or at least to illustrate his words by some striking experiment. To-night it is not in my power to do this, and I am thereby at a disadvantage. Still I value highly this opportunity which has been given me of making known to this audience the aims and purpose of the National Laboratory.

The idea of a physical laboratory in which problems bearing at once on science and industry might be solved is comparatively new. The Physikalisch-technische Reichsanstalt, founded in Berlin by the joint labors of Werner von Siemens and von Helmholtz during the years 1883–87, was perhaps the first. It is less than ten years since Dr. Lodge, in his address to Section A of the British Association, outlined the scheme of work for such an institution here in England.

Nothing came of this; a committee met and discussed plans, but it was felt to be hopeless to approach the government, and without government aid there were no funds. Four years later, however, the late Sir Douglas Galton took the matter up. In his address to the British Association in 1895 and again in a paper read before Section A, he called attention to the work done for Germany by the Reichsanstalt, and to the crying need for a similar institution in England. The result of this presidential pronouncement was the formation of a committee which reported at Liverpool, giving a rough outline of a possible scheme of organization.

A petition to Lord Salisbury followed, and as a consequence a Treasury committee, with Lord Rayleigh in the chair, was appointed to consider the desirability of establishing a National Physical Laboratory. The committee examined over thirty witnesses and then reported unanimously, "That a public institution should be founded for standardizing and verifying instruments, for testing materials, and for the determination of physical constants." It is natural to turn to the words of those who were instrumental in securing the appointment of this committee and to the evidence it received in any endeavor to dis-

* A discourse delivered at the Royal Institution.

cuss its aims. As was fitting, Sir Douglas Galton was the first witness to be called. It is a source of sorrow to his many friends that he has not lived to see the Laboratory completed.

And here I may refer to another serious loss which in the last few days this Laboratory has sustained. Sir Courtenay Boyle was a member of Lord Rayleigh's committee, and as such was convinced of the need for the laboratory and of the importance of the work it could do. He took an active part in its organization, sparing neither time nor trouble; he intended that it should be a great institution, and he had the will and the power to help. The country is the poorer by his sudden death.

Let me now quote some of Sir Douglas Galton's evidence: "Formerly our progress in machinery," he says, "was due to accuracy of measurement and that was a class of work which could be done as Whitworth showed by an educated eye and educated touch. But as we advance in the applications of science to industry we require accuracy to be carried into matters which cannot be so measured. In the more delicate researches which the physical, chemical and electrical student undertakes he requires a ready means of access to standards to enable him to compare his own work with that of others." Or again: "My view is that if Great Britain is to claim its industrial supremacy, we must have accurate standards available to our research students and to our manufacturers. I am certain that if you had them our manufacturers would gradually become very much more qualified for advancing our manufacturing industry than they are now. But it is also certain that you cannot separate some research from a standardizing department." Then after a description of the Reichsanstalt he continues, "What I would advocate would be an extension of Kew in the direction of the Second Division of the Reichsanstalt with such auxiliary research in the establishment of itself as may be found necessary." The second division is the one which takes charge of technical and industrial questions.

Professor Lodge again gave a very valuable summary of work which ought to be done. Put briefly it was this:

1. Pioneer work.
2. Verification work.
3. Systematic measurements and examination of the properties of substances under all conditions.
4. The precise determination of physical constants.
5. Observational work, testing instruments.
6. Constructional work (gratings, optical glass).
7. Designing new and more perfect instruments.

Such were the views of those who took a prominent part in the founding of the institution.

It is now realized, at any rate by the more enlightened of our leaders of industry, that science can help them. This fact, however, has

been grasped by too few in England; our rivals in Germany and America know it well, and the first aim of the laboratory is to bring its truth home to all, to assist in promoting a union which is certainly necessary if England is to retain her supremacy in trade and in manufacture, to make the forces of science available for the nation, to break down by every possible means the barrier between theory and practice, and to point out plainly the plan which must be followed, unless we are prepared to see our rivals take our place.

"Germany," an American writer,* who has recently made a study of the subject, has said, "is rapidly moving towards industrial supremacy in Europe. One of her most potent factors in this notable advance is the perfected alliance between science and commerce existing in Germany. Science has come to be regarded there as a commercial factor. If England is losing her supremacy in manufactures and in commerce, as many claim, it is because of English conservatism and the failure to utilize to the fullest extent the lessons taught by science, while Germany, once the country of dreamers and theorists, has now become intensely practical. Science there no longer seeks court and cloister, but is in open alliance with commerce and industry." It is our aim to promote this alliance in England, and for this purpose her National Physical Laboratory has been founded.

It is hardly necessary to quote chapter and verse for the assertion that the close connection between science and industry has had a predominant effect on German trade. If authority is wanted I would refer to the history of the anilin dye manufacture, or to take a more recent case, to the artificial indigo industry in which the success of the Badische Company has recently been so marked. The factory at Ludwigshaven started thirty-five years ago with thirty men. It now employs over 6,000, and has on its staff 148 trained scientific chemists. And now when it is perhaps too late the Indian planters are calling in scientific aid and the Indian government is giving some £3,500 a year to investigation.

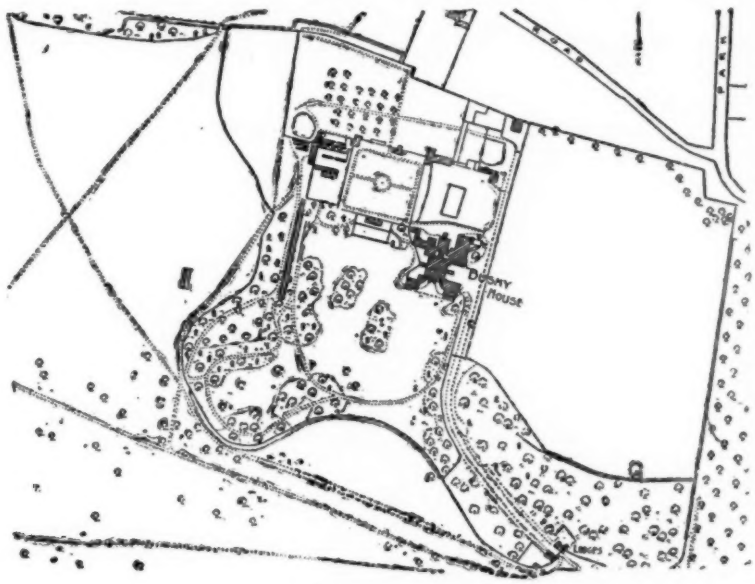
As Professor Armstrong, in a recent letter to the 'Times,' says: "The truly serious side of the matter, however, is not the prospective loss of the entire indigo industry so much as the fact that an achievement such as that of the Badische Company seems past praying for here."

Or, to take another instance, scientific visitors to the Paris Exhibition last year must have been struck by the German exhibit of apparatus. German instrument makers combined to produce a joint exhibit; a strong committee was formed. Under the skilful editorship of Dr. Lindeck of the Reichsanstalt a catalogue was compiled, in which by a judicious arrangement of cross references it was easily

* Professor H. S. Carhart.

possible to find either the exhibit of a particular firm or the apparatus of a particular class. This was printed in German, English and French, and issued freely to visitors. Dr. Drosten, the representative of the exhibitors in charge, or one of his assistants, was ever ready to give information and advice. To one who wished, as I did, to see the most modern forms of German apparatus, the exhibit was a very real help. Let me quote a few lines from the catalogue:

At the commencement of the nineteenth century, the French and English makers of scientific instruments were far in advance of the Germans. True, the eighteenth century had its prominent mechanics in Germany, yet at the



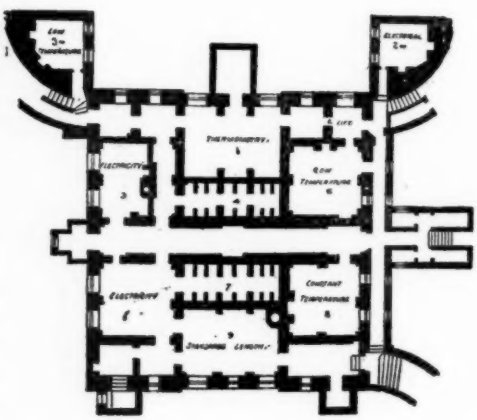
PLAN OF GROUNDS.

beginning of the nineteenth century French and English makers took the lead, so as to almost supply the world's entire demand in scientific instruments. This predominance had the further consequence of causing young Germans to emigrate to France or England in order thoroughly to master their subject. Many a German mechanic to-day owes to French or English masters a substantial portion of his knowledge. And then in Germany it is only within the last twenty or twenty-five years that the state has espoused the interests of the home industry, but such have been the efforts and the results that the position has at a blow, as it were, changed in favor of Germany. The greatest share of the impetus given to the manufacture of scientific instruments is due to the Reichsanstalt. A characteristic feature of this trade is the unity of its aims, which is traceable to the history of its development and its intimate connection with pure science. During the year 1898 the value of German exports of scientific instruments was about a quarter of a million sterling. It had trebled within ten years; while nearly 14,000 people were employed in it.

And now having stated in general terms the aims of the laboratory and given some account of the progress in general, let me pass to some description of the means which have been placed at our disposal to realize those aims. I here wish, if time permits, to discuss in fuller detail some of the work which it is hoped we may take up immediately.

BUSHY HOUSE, GROUND PLAN.

The laboratory is to be at Bushy House, Teddington. I will pass over the events which led to this change of site from the old Deer Park at Richmond to Bushy. It is sufficient to say that at present Kew Observatory in the Deer Park will remain as the observatory department of the laboratory, and most of the important verification and standardization work which in the past has been done there will still find its home in the old building. The house was originally the official residence of the Ranger of Bushy Park. Queen Anne granted it in 1710 to the first Lord Halifax. In 1771 it passed to Lord North, being then probably rebuilt. Upon the death of Lord North's widow, in 1797, the Duke of Clarence, afterwards William IV., became Ranger. After his death in 1837 it was granted to his widow, Queen Adelaide, who lived here until 1849. At her death it passed to the Duc de Nemours, son of King Louis Philippe, and he resided here at intervals until 1896. In spite of this somewhat aristocratic history it will make an admirable laboratory. The building is very solid and substantial. There is a good basement under the main central block with roof of brick groining, which makes a very steady support for the floor above.



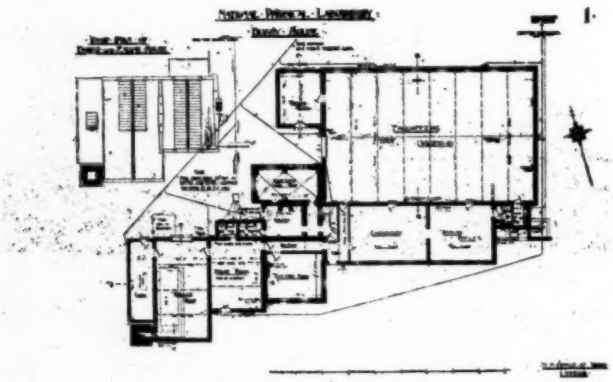
BUSHY HOUSE, BASEMENT.

BUSHY HOUSE, EAST FRONT.

BUSHY HOUSE, SOUTH FRONT

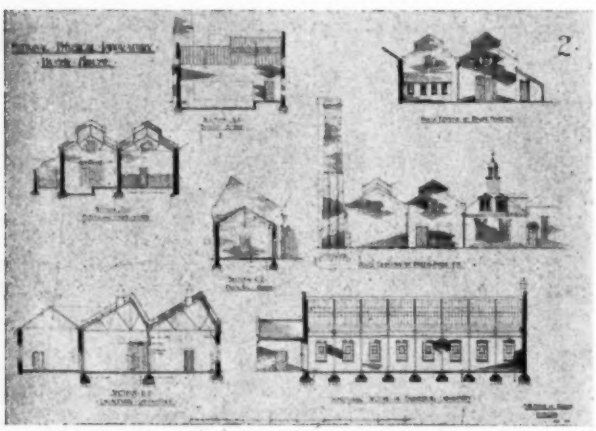
Such is the home of the laboratory. It may be of interest to compare it with the Reichsanstalt.

The floor space available is much less than that of the Reichsanstalt. But size alone is not an unmixed advantage; there is much to be said



ENGINEERING LABORATORY, GROUND PLAN.

in favor of gradual growth and development, provided the conditions are such as to favor growth. Personally I would prefer to begin in a small way, if only I felt sure I was in a position to do the work thoroughly, but there is danger of starvation. Even with all the help we



ENGINEERING LABORATORY, ELEVATIONS AND SECTIONS.

get in freedom from rent and taxes, outside repairs and maintenance, the sum at the disposal of the committee is too small. £14,000 will not build and equip the laboratory. £4,000 a year will not maintain it as it ought to be maintained. Contrast this with the expenditure on the Reichsanstalt or with the proposals in America where the bill

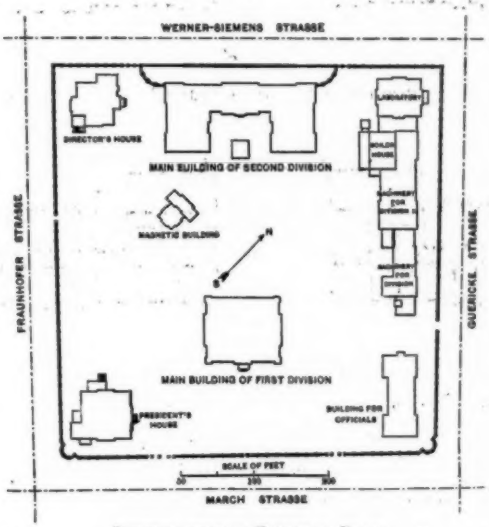
for the establishment of a laboratory has just passed, and an expenditure of £60,000 on building and site and £9,000 a year has been authorized.

CAPITAL EXPENDITURE ON THE REICHSANSTALT.

DIVISION I.		
Site – the Gift of Dr. Siemens	£25,000	
Cost of Buildings	34,275	
Fittings and Furniture	2,700	
Machinery and Instruments	4,100	
		£66,075
DIVISION II.		
Site	£18,600	
Buildings	88,000	
Fittings and Furniture	5,400	
Machinery and Instruments	23,550	
		135,550
		£201,625

ANNUAL EXPENDITURE.

Salaries and Wages	£10,300
Maintenance of Buildings, Apparatus, etc.	6,350
	£16,650



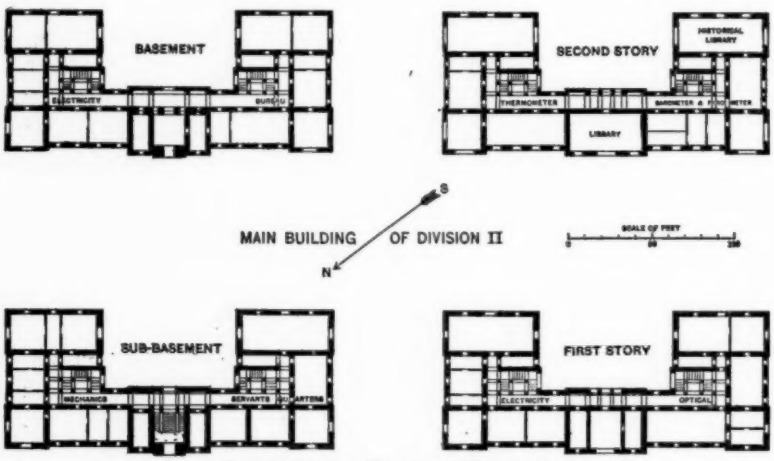
REICHSANSTALT, GENERAL PLAN.

Science is not yet regarded as a commercial factor in England. Is there no one who, realizing the importance of the alliance, will come forward with more ample funds to start us on our course with a fair prospect of success? One real friend has recently told us in print that the new institution is on such a microscopic scale that its utility in the present struggle is more than doubtful. Is there no statesman who can grasp the position and see that, with say double the income,

the chances of our doing a great work would be increased a hundredfold? The problems we have to solve are hard enough; give us means to employ the best men and we will answer them, starve us and then quote our failure as showing the uselessness of science applied to industry. There is some justice in the criticism of one of our technical papers. I have recently been advertising for assistants, and a paper in whose columns the advertisement appeared writes:

The scale of pay is certainly not extravagant. It is however possible that the duties will be correspondingly light.

I have thus summarized in a brief manner the aims of the laboratory and have indicated the effect which the application of science to industry has had on one branch of trade in Germany. And now let me illustrate these aims by a more detailed account of some of the problems of industry which have been solved by the application of



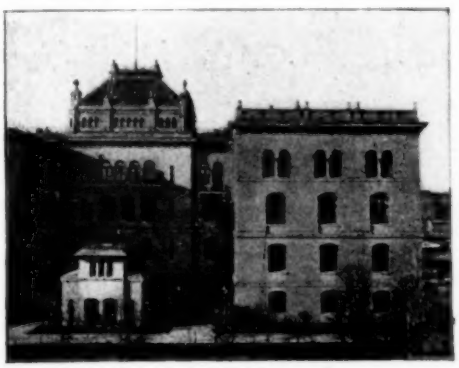
REICHSANSTALT, TECHNICAL BUILDING.

science, and then of some others which remain unsolved and which the laboratory hopes to attack. The story of the Jena glass-works is most interesting; we will take it first.

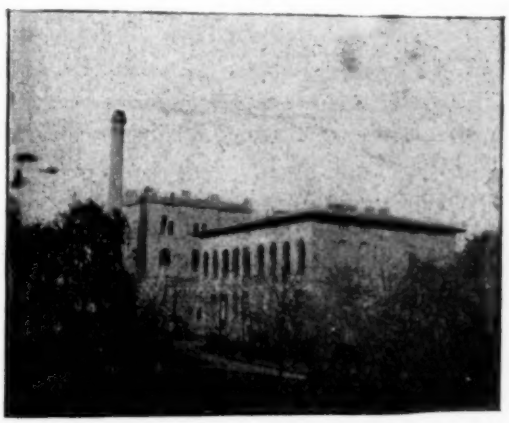
An exhibition of scientific apparatus took place in London in 1878. Among the visitors to this was Professor Abbé, of Jena, and in a report he wrote on the optical apparatus he called attention to the need for progress in the art of glass-making if the microscope were to advance and to the necessity for obtaining glasses having a different relation between dispersion and refractive index than that found in the material at the disposal of opticians. Stokes and Harcourt had already made attempts in this direction but with no marked success. In 1881 Abbé and Schott at Jena started their work. Their undertaking, they write five years later in the first catalogue of their factory, arose out of a scientific investigation into the connection between the optical proper-

ties of solid amorphous fluxes and their chemical constitution. When they began their work some six elements only entered into the composition of glass. By 1888 it had been found possible to combine with these in quantities up to about 10 per cent. twenty-eight different elements, and the effect of each of these on the refractive index and dispersion had been measured. Thus for example the investigators found that by the addition of boron the ratio of the length of the blue end of the spectrum to that of the red was increased; the addition of fluorine, potassium or sodium produced the opposite result. Now in an ordinary achromatic lens of crown and flint, if the total dispersion for the two be the same, then for the flint glass the dispersion of the blue end is greater; that of the red less than for the crown; thus the image is not white, a secondary spectrum is the result. Abbé showed, as Stokes and Harcourt had shown earlier, that by combining a large proportion of boron with the flint its dispersion was made more nearly the same as that of the crown, while by replacing the silicates in the crown glass by phosphates a still better result was obtained, and by the use of three glasses three

REICHSANSTALT, DIVISION I., MAIN BUILDING.



REICHSANSTALT, DIVISION II., MAIN BUILDING.



REICHSANSTALT, BUILDING FOR LARGE CURRENTS AND MACHINERY.

lines of the spectrum could be combined. The spectrum outstanding was a tertiary one and much less marked than that due to the original crown and flint glass. The modern microscope became possible.

The conditions to be satisfied in a photographic lens differ from those required for a microscope. Von Seidel had shown that with the ordinary flint and crown glasses the conditions for achromatism and for flatness of field cannot be simultaneously satisfied. To do this we need a glass of high refractive index and low dispersive power or vice versa; in ordinary glasses these two properties rise and fall together. Thus crown glass has a refractive index of 1.518 and a dispersive power of .0166, while for flint the figures are 1.717 and .0339. By introducing barium into the crown glass a change is produced in this respect. For barium crown the refractive index is greater and the dispersive power less than for soft crown. With two such glasses then the field can be achromatic and flat. The wonderful results obtained by Dallmeyer and Ross in this country, by Zeiss and Steinheil in Germany, are due to the use of new glasses. They have also been applied with marked success to the manufacture of the object glasses of large telescopes.

But the Jena glasses have other uses besides optical. "About twenty years ago"—the quotation is from the catalogue of the German Exhibition—"the manufacture of thermometers had come to a dead stop in Germany, thermometers being then invested with a defect, their liability to periodic changes, which seriously endangered German manufacture. Comprehensive investigations were then carried out by the Normal Aichungs Commission, the Reichsanstalt, and the Jena glass works, and much labor brought the desired reward." The defect referred to was the temporary depression of the ice point which takes place in all thermometers after heating. Let the ice point of a thermometer be observed; then raise the thermometer to say 100° and again observe the ice point as soon as possible afterwards; it will be depressed below its previous position; in some instruments of Thuringian glass a depression of as much as 0°.65 C. had been noted. For scientific purposes such an instrument is quite untrustworthy. If it be kept at say 15° and then immersed in a bath at 30° it will be appreciably different from that which would be given if it were first raised to say 50°, allowed to cool quickly just below 30°, and then put into the bath. This was the defect which the investigators set themselves to cure.

DEPRESSION OF FREEZING POINT FOR VARIOUS THERMOMETERS.

Humboldt	1835	0°.06
Greiner	1872	0 .38
Schultzer	1875	0 .44

Rapps	1878	0 .65
English Glass		0 .15
Ver Deer		0 .08
16‴		0 .05
59‴		0 .02

ANALYSIS OF GLASSES.

	SiO_2	Na_2O	CaO	Al_2O_3	ZnO	B_2O_3
16‴	67.5	14	7	2.5	7	2
59‴	72	11		5		12

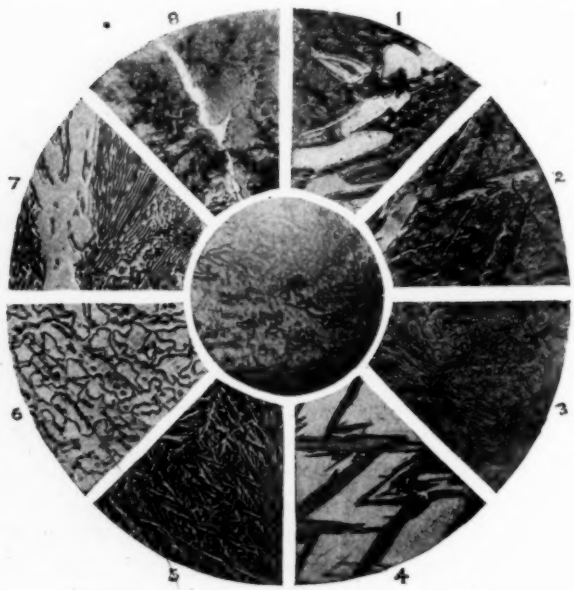
Weber had found in 1883 that glasses which contain a mixture of soda and potash give a very large depression. He made in 1883 a glass free from soda with a depression of 0°.1. The work was then taken up by the Aichungs Commission, the Reichsanstalt, and the Jena factory. Weber's results were confirmed. An old thermometer of Humboldt's containing 0.86 per cent. of soda and 20 per cent. of potash had a depression of 0°.06, while a new instrument, in which the percentages were 12.7 per cent. and 10.6 per cent., respectively, had a depression of 0°.65. An English standard, with 1.5 per cent. of soda, 12.3 per cent. of potash, gave a depression of 0°.15, while a French 'Ver deer' instrument in which these proportions were reversed gave only 0°.08. It remained to manufacture a glass which should have a low depression and at the same time other satisfactory properties. The now well-known glass 16‴ is the result. Its composition is shown in the table. The fact that there was an appreciable difference between the scale of the 16‴ glass and that of the air thermometer led to further investigation, and another glass, a borosilicate, containing 12 per cent. of boron, was the consequence. This glass has a still smaller depression. As a result of this work Germany can now claim that 'the manufacture of thermometers has reached in Germany an unprecedented level and now governs the markets of the world.'

Previous to 1888 Germany imported optical glass; at that date nearly all the glass required was of home manufacture. Very shortly afterwards an export trade in raw glass began, which in 1898 was worth £30,000 per annum, while the value of optical instruments, such as telescopes, field glasses, and the like, exported that year was over £250,000. Such are the results of the application of science, *i. e.*, organized common sense, to a great industry. The National Physical Laboratory aims at doing the like for England.

The question of standardization of patterns and designs is probably too large a one to go into on the present occasion. Some months ago a most interesting discussion of the subject took place at the Institution of Electrical Engineers. To my mind there is no doubt that the judicious adoption of standard types combined with readiness to scrap old patterns, so soon as a real advance or improvement is made, is necessary for progress. One who has been over some good German

workshop or has contrasted a first-class English shop where this is the practice with an old-fashioned establishment where standardization is hardly known, can have no hesitation on this question. It has its disadvantages, less is left to the originality of the workman and in consequence they lose the power of adaptation to new circumstances and conditions. The English mechanic is I believe greatly superior to the German, but the scientific organization of the German shops enables them to compete successfully with the English.

In 1881 the German Association of Mechanics and Opticians was formed, having for its aim the scientific, technical and commercial development of instrument making. The society has its official organ, the 'Zeitschrift für Instrumentenkunde,' edited by one of the staff of



SECTION OF IRON AFTER VARIOUS TREATMENTS.

Specimen.

1. Raised to 1000°. Worked and cooled slowly. Masses of carbide ground work, bands of iron and carbide, *pearlite structure.*

2. Raised to 850° and quickly cooled. Masses disappear.

3. Raised to 850° and quenched in water. Arcicular structure. Martensite, hard steel.

4. Raised to 1050° and quenched in iced brine. Martensite and Austenite.

5. Same cooled in liquid air to — 243. Much like martensite.

6. Heated to near melting point, quenched suddenly burnt steel.

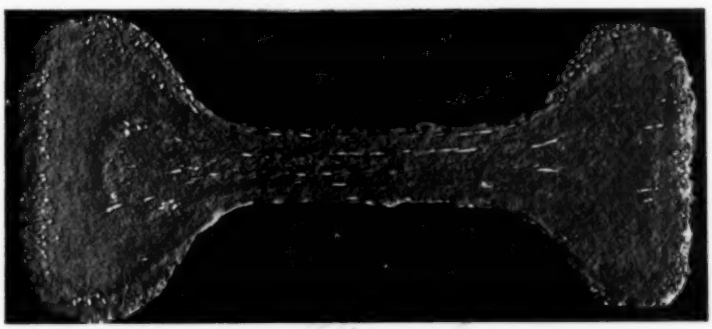
7. Heated to 650°—annealed for a long time at this temperature and slowly cooled, bands of carbide and pearlite.

8. Any specimen except 6 heated to 850, worked and slowly cooled, giving us the structure 1.

Very marked changes might have been produced in 3 by annealing at 140°.

the Reichsanstalt. Specialized schools for the training of young mechanics in the scientific side of their calling have been formed and now the majority of the leading firms retain in their permanent service one or more trained mathematicians or physicists. In this way again the importance of science to industry is recognized. I have thus noted very briefly some of the ways in which science has become identified with trade in Germany, and have indicated some of the investigations by which the staff of the Reichsanstalt and others have advanced manufactures and commerce.

Let us turn now to the other side, to some of the problems which remain unsolved, to the work which our laboratory is to do and by doing which it will realize the aims of its founders. The microscopic examination of metals was begun by Sorby in 1864. Since that date many distinguished experimenters, Andrews, Arnold, Ewing, Martens, Osmond, Roberts-Austen, Stead and others have added much to our knowledge. I am indebted to Sir W. Roberts-Austen for the slides which I am about to show you to illustrate some of the points arrived at. Professor Ewing a year ago laid before the Royal Institution the results of the experiment of Mr. Rosenhain and himself. This microscopic work has revealed to us the fact that steel must be regarded as a crystallized igneous rock. Moreover, it is capable at temperatures far below its melting point of altering its structure completely, and its mechanical and magnetic properties are intimately related to its structure. The chemical constitution of the steel may be unaltered, the amounts of carbon, silicon, manganese, etc., in the different forms remain the same, but the structure changes, and with it the properties of the steel. The figure on page 136 represents sections of the same steel polished and etched after various treatments.

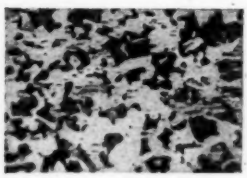


SECTION OF BAD RAIL.

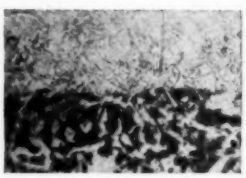
The steel is a highly carbonized form, containing 1.5 per cent. of carbon. If it be cooled down from the liquid state, the temperature being read by the deflexion of a galvanometer needle in circuit with a

thermopile, the galvanometer shows a slowly falling temperature till we reach 1380° C., when solidification takes place. The changes which now go on take place in solid metal. After a time the temperature again falls until we reach 680°, when there is an evolution of heat; had the steel been free from carbon there would have been evolution of heat at 895° and again at 766°. Now throughout the cooling molecular changes are going on in the steel. By quenching the steel suddenly at any given temperature we can check the change and examine microscopically the structure of the steel at the temperature at which it was checked.

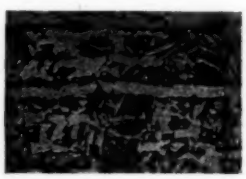
In the figure, with the exception of specimen No. 6, the metal has not been heated above 1050°, over 300° below its melting point.



SECTION OF GOOD RAIL.



SECTION OF BAD RAIL, SHOWING SURFACE TO WHICH FRACTURE WAS DUE.



SECTION OF RAIL AFTER ROLLING.

At temperatures between about 900° and 1100° the carbon exists in the form of carbide of iron dissolved in the iron, at a temperature of 890° the iron which can exist in different forms as an allotropic substance passes from the γ form to the β form, and in this form cannot dissolve more than .9 per cent. of carbon as carbide. Thus at this temperature a large proportion of the carbon passes out of the solution. At 680° the remainder of the carbide falls out of the solution as lamina.

Thus the following temperatures must be noted: 1380°, melting point; 1050°, highest point reached by specimen; 890°, .6 per cent. of carbon deposited; 680°, rest of carbide deposited.

To turn now to the details of the photo, the center piece is the cemented steel as it comes from the furnace after the usual treatment.

These slides are sufficient to call attention to the changes which occur in solid iron, changes whose importance is now beginning to be realized. On viewing them it is a natural question to ask how all the other properties of iron related to its structure; can we by special treatment produce a steel more suited to the shipbuilder, the railway engineer or the dynamo maker than any he now possesses?

These marked effects are connected with variations in the condition of the carbon in the iron; can equally or possibly more marked changes be produced by the introduction of some other elements? Guillaume's

nickel steel with its small coefficient of expansion appears to have a future for many purposes; can it by some modification be made still more useful to the engineer?

We owe much to the work of the Alloys Research Committee of the Institution of Mechanical Engineers. Their distinguished chairman takes the view that the work of that committee has only begun and that there is scope for research for a long time to come at the National Physical Laboratory, and the executive committee have accepted this view by naming as one of the first subjects to be investigated the connection between the magnetic quality and the physical, chemical and electrical properties of iron and its alloys with a view specially to the determination of the conditions for low hysteresis and non-aging properties.

At any rate we may trust that the condition of affairs mentioned by Mr. Hadfield in his evidence before Lord Rayleigh's commission which led a user of English steel to specify that before the steel could be accepted it must be stamped at the Reichsanstalt will no longer exist.

The subject of wind pressure again is one which has occupied the committee's attention to some extent.

The Board of Trade rules require for bridges and similar structures (1) that a maximum pressure of 56 pounds per square foot be provided for, (2) that the effective surface on which the wind acts should be assumed as from once to twice the area of the front surface according to the extent of the openings in the lattice girders, (3) that a factor of safety of 4 for the iron work and of 2 for the whole bridge overturning be assumed. These recommendations were not based on any special experiments. The question had been investigated in part by the late Sir Wm. Siemens.

During the construction of the Forth Bridge Sir B. Baker conducted a series of observations.

TABLE II.

Revolving Gauge Mean Pressure.		Small Fixed Gauge.		Large Fixed Gauge.	
		Easterly.	Westerly.	Easterly.	Westerly.
W.	W.	W.	W.	W.	W.
0 to 5	3.09	3.47	2.92	2.04	1.9
5 to 10	7.58	4.8	7.7	3.54	4.75
10 to 15	12.4	6.27	13.2	4.55	8.26
15 to 20	17.06	7.4	17.9	5.5	12.66
20 to 25	21.0	12.25	22.75	8.6	19
25 to 30	27.0		28.5		18.25
30 to 35	32.5		38.5		21.5
Above	65		41.0		35.25
(One observation only above 32.5.)					

The results of the first two years' observations are shown in Table II. taken from a paper read at the British Association in 1884. Three

gauges were used. In No. 1 the surface on which the wind acted was about 1½ square feet in area; it was swiveled so as always to be at right angles to the wind. In No. 2 the area of surface acted on was of the same size but was fixed with its plane north and south. No. 3 was also fixed in the same direction but it had 200 times the area, its surface being 300 square feet.

In preparing the table the mean of all the readings of the revolving gauge between 0 and 5, 5 and 10, etc., pounds per square foot have been taken and the mean of the corresponding readings of the small fixed gauge and the large fixed gauge set opposite, these being arranged for easterly and westerly winds.

Two points are to be noticed: (1) There is only one reading of over 32.5 pounds registered, and this it is practically certain is due to faulty action in the gauge. Sir B. Baker has kindly shown me some further records with a small gauge.

According to these pressures of over 50 pounds have been registered on three occasions since 1886. On two other occasions the pressures as registered reached from 40 to 50 pounds per square foot. But the table, it will be seen, enables us to compare the pressure on a small area with the average pressure on a large area, and it is clear that in all cases the pressure per square foot as given by the large area is much less than that deduced from the simultaneous observations on the small area.

The large gauge became unsafe in 1896 and was removed, but the observations for the previous ten years entirely confirm this result, the importance of which is obvious. The same result may be deduced from the Tower Bridge observations. Power is required to raise the great bascules and the power needed depends on the direction of the wind. From observations on the power some estimate of the average wind pressure on the surface may be obtained, and this is found to be less than the pressure registered by the small wind gauges.

Nor is the result surprising when the matter is looked at as an hydrodynamical problem—the wind blows in gusts—the lines of flow near a small obstacle will differ from those near a large one; the distribution of pressure over the large area will not be uniform. Sir W. Siemens is said to have found places of negative pressure near such an obstacle. As Sir J. Wolfe Barry has pointed out, if the average of 56 pounds to the square foot is excessive then the cost and difficulty of erection of large engineering works is being unnecessarily increased. Here is a problem well worthy of attention and about which but little is known. The same too may be said about the second of the Board of Trade rules. What is the effective surface over which the pressure is exerted on a bridge? On this again our information is but scanty. Sir B. Baker's experiments for the Forth Bridge led him to adopt as his rule double

the plane surface exposed to the wind and deduct 50 per cent. in the case of tubes. On this point again further experiments are needed.

To turn from engineering to physics. In metrology as in many other branches of science difficulties connected with the measurement of temperature are of the first importance.

I was asked some little time since to state to a very high order of exactness the relation between the yard and the meter. I could not give the number of figures required. The meter is defined at the freezing point of water, the yard at a temperature of 62° Fahr. When a yard and meter scale are compared they are usually at about the same temperature; the difficulty of the comparison is enormously increased if there be a temperature difference of 30° Fahr. between the two scales. Hence we require to know the temperature coefficients of the two standards. But that of the standard yard is not known; it is doubtful, I believe, if the composition of the alloy of which it is made is known, and in consequence Mr. Chaney has mentioned the determination of coefficients of expansion as one of the investigations which it is desirable that the Laboratory should undertake.

Or again take thermometry. The standard scale of temperature is that of the hydrogen thermometer; the scale in practical use in England is the mercury in flint glass scale of the Kew standard thermometers. It is obvious that it is of importance to science that the difference between the scales should be known and various attempts have been made to compare them.

But the results of no two series of observations which have been made agree satisfactorily. The variations arise probably in great measure from the fact that the English glass thermometer as ordinarily made and used is incapable of the accuracy now demanded for scientific investigation. The temporary depression of the freezing point already alluded to in discussing the Jena glass is too large; it may amount to three to four tenths of a degree when the thermometer is raised 100°. Thus the results of any given comparison depend too much on the immediate past history of the thermometer employed, and it is almost hopeless to construct a table accurate, say, to .01 which will give the difference between the Kew standard and the hydrogen scale and so enable the results of former work in which English thermometers were used to be expressed in standard degrees.

VALUES OF CORRECTIONS TO THE ENGLISH GLASS THERMOMETER SCALE TO GIVE TEMPERATURES ON THE GAS THERMOMETER SCALE FOUND BY VARIOUS OBSERVERS.

Temp.	Rowland.	Guillaume.	Wiebe.
0	0°	0°	0
10	—.03	—.009	+.03
20	—.05	—.009	+.00

30	—.06	—.002	+.02
40	—.07	+.007	+.09
50	—.07	+.016	+.14
60	—.06	+.014	
70	—.04	+.028	
80	—.02	+.026	
90	—.01	+.017	
100	0	0	

This is illustrated by giving the differences as found, (1) by Rowland, (2) by Guillaume, (3) by Wiebe, between a Kew thermometer and the air thermometer. It is clearly important to establish in England a mercury scale of temperatures which shall be comparable with the hydrogen scale, and it is desirable to determine as nearly as may be the relation between this and the existing Kew scale.

I am glad to say that in this endeavor we have secured the valuable cooperation of Mr. Powell, of the Whitefriars works, and that the first specimens of glass he has submitted to us bid fair to compare well with the 16″. Another branch of thermometry at which there is much to do is the measurement of high temperature. Professor Callendar has explained here the principles of the resistance thermometer, due first to Sir W. Siemens. Sir W. C. Roberts-Austen has shown how the thermopile of Le Chatellier may be used for the measurement of high temperatures. There is a great work left for the man who can introduce these or similar instruments to the manufactory and the forge, or who can improve them in such a manner as to render their uses more simple and more sure. Besides, at temperatures much over 1000° C. the glaze on the porcelain tube of the pyrometer gives way, the furnace gases get in to the wire and are absorbed and the indications become untrustworthy. We hope it may be possible to utilize the silica tubes shown here by Mr. Shenstone a short time since in a manner which will help us to overcome some of these difficulties. Here is another subject of investigation for which there is ample scope.

So far we have discussed new work, but there is much to be done in extending a class of work which has gone on quietly and without much show for many years at the Kew Observatory.

Thermometers and barometers, wind gauges and other meteorological apparatus, watches and chronometers and many other instruments are tested there in great numbers and the value of the work is undoubted. The competition among the best makers for the first place, the best watch of the year, is most striking and affords ample testimony to the importance of the work. Work of this class we propose to extend.

Thus there is no place where pressure gauges or steam indicators can be tested. It is intended to take up this work, and for this purpose a mercury pressure column is being erected. Bushy House from basement to eaves is about 55 feet in height. We hope to have a column of about 50 feet in height, giving a pressure of about 20 atmospheres; it

is too little, but it is all we can do with our present building. The necessary pumps are being fitted to give the pressure and we shall have a lift set up along the column so that the observer can easily read the height of the mercury.

This column will serve to graduate our standard gauges up to 20 atmospheres, above that we may for the present have recourse to some multiplying device; a very beautiful one is used at the Reichsanstalt and by Messrs. Schaffer and Budenberg, but we are told we must improve on this.

Again, there are the ordinary gauges in use in nearly every engineering shop. These in the first instance have probably come from Whitworth's or nowadays, I fear, from Messrs. Pratt & Whitney or Brown & Sharp, of America; they were probably very accurate when new but they wear, and it is only in comparatively few large shops that means exist for measuring the error and for determining whether the gauge ought to be rejected or not.

Hence arise difficulties of all kinds. Standardization of work is impossible. The new screw sent out to South Africa to replace one damaged in the war will not fit, and the gun is useless. A long range of steam piping is wanted; the best angle pieces and unions are made by a firm whose screwing tackle differs slightly from that of the factory where the pipes were ordered. Delays and difficulties of all kinds occur which ready means for standardization would have avoided. Here is scope for work if only manufacturers will utilize the opportunities we hope to give them.

In another direction a wide field is offered in the calibration and standardization of glass measuring vessels of all kinds—flasks, burettes, pipettes, etc.—used by chemists and others. At the request of the Board of Agriculture we have already arranged for the standardization of the glass vessels used in the Babcock method of measuring the butter fat in milk and in a few months many of these have passed through our hands. We are now being asked to arrange for testing the apparatus for the Gerber & Leffman-Beam methods, and this we have promised to do when we are settled at Bushy. Telescopes, opera glasses, sextants and other optical appliances are already tested at Kew, but this work can and will be extended. Photographic lenses are now examined by eye; a photographic test will be added. And I trust the whole may be made more useful to photographers.

I look to the cooperation of the Optical Society to advise how we may be of service to them in testing spectacles, microscope lenses and the like.

The magnetic testing of specimens of iron and steel again offers a fertile field for enquiry.

If more subjects are needed it is sufficient to turn over the pages

of the evidence given before Lord Rayleigh's commission or to look to the reports which have been prepared by various bodies of experts for the Executive Committee.

In electrical matters there are questions relating to the fundamental units on which in Mr. Trotter's opinion we may help the officials of the Board of Trade—standards of capacity are wanted; those belonging to the British Association will be deposited at the Laboratory; standards of electromagnetic induction are desirable; questions continually arise with regard to new forms of cells other than the standard Clark cell, and in a host of other ways work could be found. Tests on insulation resistance were mentioned by Professor Ayrton who gave the result of his own experience. He had asked for wire having a certain standard of insulation resistance. One specimen was eight times as good as the specification; another had only one one-hundred-thousandth of the required insulation; a third had about one three-hundredth.

Mr. Appleyard again gave some interesting examples, the examination of alloys for use for resistance measurements and other purposes, the testing of various insulating materials and the like.

I have gone almost too much into detail. It has been my wish to state in general terms the aims of the laboratory, to make the advance of physical science more readily available for the needs of the nation and then to illustrate the way in which it is intended to attain those aims. I trust I may have shown that the National Physical Laboratory is an institution which may deservedly claim the cordial support of all who are interested in real progress.

CEMENT FOR A MODERN STREET.

By Dr. S. F. PECKHAM.

A MODERN street consists of a concrete foundation which extends from curb to curb, upon which is laid a wearing surface of asphalt, brick or other material.

The use of these concretes has an instructive history, which might be profitably preceded by a discussion of the uses of mortars and cements in antiquity, did space permit. So far as I have been able to learn, all the different varieties of cementing materials, including ordinary lime mortars, have been experimented with for the construction of concrete foundations. It is therefore proper that these different materials should be briefly described.

Mortar, in the ordinary sense of the term, designates a mixture of lime and sand. The lime is prepared by heating limestone in kilns, until the carbonic acid of the limestone is expelled and oxide of calcium remains, which readily absorbs water and slacks, as it is termed, and in time reabsorbs the carbonic acid that was driven off. The lime is mixed with the water when it is slacked and the carbonic acid is absorbed from the atmosphere. When mortar is made, the lime is first made into a thin paste with water, and sand is added until the mass ceases to be sticky. Such mortar acquires strength slowly. The excess of water first dries out and then the lime by slow absorption of carbonic acid forms thin particles of limestone between the grains of sand, until the mortar becomes a coherent mass. That this process goes on very slowly is shown by the fact that the mortar between the bricks of chimneys centuries old is found to contain a considerable percentage of unchanged lime. This mortar, when first laid, will not bear wetting, and will set only in dry air.

The Romans had learned before the Christian Era that the addition to lime mortar of volcanic ash or pozzuolana would make the mortar set under water and with additional strength. The so-called Roman cement was noted in antiquity for its superior strength when compared with ordinary lime mortar. Where they could not obtain the pozzuolana they used pulverized brick and pottery.

During the middle ages, for more than a thousand years, the art of making hydraulic cement was lost, and, with every other art, the art of making good mortar declined until the beginning of the eighteenth century, when attempts were made to revive the art of making Roman cement, but with only slight success.

In the year 1756, the celebrated engineer, John Smeaton, was wrestling with the problem of constructing the Eddystone Lighthouse. While experimenting with different varieties of mortar, he discovered that certain limestones produced an hydraulic lime. He found that a mortar made of pure lime and pozzuolana or powdered bricks gave only unsatisfactory results, but when an impure lime from the 'Alberthaw' was used the hydraulic properties were more fully developed. Continuing his experiments, he at length announced that only limestones containing clay produced a lime of satisfactory hydraulic properties.

Speaking of this discovery, Smeaton says in his 'Narrative of the Eddystone Lighthouse':

> It remains a curious question, which I must leave for learned naturalists and chemists, why an intermediate mixture of clay in the composition of limestone of any kind, either hard or soft, should render it capable of setting in water in a manner no pure lime I have yet seen, from any kind of stone whatever, is capable of doing.
>
> It is easy to add clay in any proportion to pure lime, but it produces no such effect; it is easy to add brick dust, either finely or coarsely powdered, to such lime in any proportions also; but this seems unattended with any other effect than what arises from other bodies becoming porous and spongy and therefore absorbent of water as already hinted and excepting what may reasonably be attributed to the irony particles that red brick dust may contain.
>
> In short, I have as yet found no treatment of pure calcareous lime that renders it more fit to set in water than it is by nature, except what is to be derived from the admixture of trass, pozzuolana and some ferruginous substance of similar nature.

These investigations and the conclusions that he drew from them led Smeaton to use in the construction of the Eddystone Lighthouse a mortar or cement composed of hydraulic lime from the Alberthaw and Italian pozzuolana. A step or two farther in his investigations, which he did not take and which were not taken until the middle of the last century, would have led to the Portland Cement of the present time.

In 1796, a Mr. Parker, of London, patented a process for what he called 'Roman Cement.' He used for this purpose certain nodules of limestone containing clay that were found along the coasts of the Isle of Sheppy and certain parts of Kent and Essex. These nodules were first calcined and then reduced to fine powder in mills. The result was a cement of a better quality than Smeaton's. In 1818, one Canvass White discovered and patented in the United States a process for making cement from a similar rock, found at Fayetteville, in central New York. Large quantities were manufactured and used in the construction of locks on the Erie Canal, which was then being built. The State of New York purchased the patent and made it public property. This laid the foundation of a great industry, which is known generally

as the 'Natural Cement Industry,' but locally in the neighborhood of New York City as the Rosendale Cement Industry.

Continuing these experiments it was found that the rocks found in a few localities produced cements of a quality superior to those in general use. This was particularly true of a stone found in the Island of Portland. At length artificial mixtures of limestone and clay were made and burned under such conditions that the resulting cement very closely resembled the natural cement made from the Portland rock. These results led to the adoption of the name of Portland for all cements of this class, whether made in England, where the name originated, or elsewhere. The first attempts to prepare a cement by artificial mixtures, in imitation of the natural Portland rock, were made in France about 1802.

Portland cements, as at present manufactured, were first made in England by a process that was patented in 1824, although there had been several patents for 'Portland Cements' previously issued. In the patent specifications of 1824 occurs the following description of the process used:

> **I take a specific quantity of limestone and calcine it. I then take a specific quantity of clay and mix it with water to a state approaching impalpability. After this proceeding I put the above mixture into a slip-pan for evaporation till the water is entirely evaporated. Then I break the said mixture into suitable lumps and calcine them in a furnace similar to a lime-kiln until the carbonic acid is entirely expelled. The mixture, so calcined, is to be ground to a fine powder, and it is then in a fit state for cementing. The powder is to be mixed with a sufficient quantity of water to bring it into the consistency of mortar, and this applied to the purposes wanted.**

It will thus be seen that at the middle of the last century there were in use: Common lime mortar, consisting of slacked lime and sand; made all over the world and used for common masonry and plastering.

Also Roman cement, made by mixing common lime and some dry aluminous material, like pulverized tufa, brick or slag. This was stronger than common mortar and slightly hydraulic.

Also, natural cement, called Rosendale cement in the United States, made by burning and grinding a natural limestone containing clay. These natural cements are of very varying quality and are hydraulic, *i. e.*, will set or harden under water.

Also, Portland cements, called also Artificial cements, made by grinding limestone or marl, both of which are nearly pure carbonate of lime, and mixing it in proper proportions with ground clay, which is a silicate of alumina containing a variable proportion of the oxides of iron. This mixture is calcined at a temperature that will produce semi-fusion and the resulting clinker is ground to a fine powder. The powder is 'aged' in order to partially slack the lime. The powder is mixed with

sand and water to the consistency of mortar and used. Like natural cement, Portland cements are hydraulic, and they make the strongest mortars known.

A modern street consists of a foundation of broken stone that is formed into a concrete or solid mass of masonry by admixture with mortar. The character and quality of this mortar are a matter of the greatest importance. All of the four kinds of mortar mentioned above have been used for this purpose.

An experiment was made in London by laying in Holborn, opposite Gray's Inn, nine inches of lime mortar concrete with a floating on top of ¾ inches of lime mortar. Upon this foundation was laid a surface of Val de Travers asphalte. When the concrete was ready to receive the

FIG. 1. COAL DUMPS AND INCLINES TO KILNS.

asphalte, a fire broke out in Holborn; the place was flooded with water, the engines drove over the concrete and the population of Gray's Inn trampled it down. It was subsequently made good and the asphalte spread. For five or six years the road was kept up at considerable expense and then relaid. On removing the asphalte, it was found that the lime concrete had never set, that the mortar floating had never adhered to the concrete, but was mostly in powder, produced either by the action of the rammers or by the traffic afterwards.

Roman cement was tried in Paris and condemned for street foundations. There remains for use for this purpose natural cement

and Portland cement. The details of the process of manufacture will now be given.

In the United States the manufacture of natural cements is chiefly carried on in the Lehigh Valley, near Louisville, Ky., at Akron, Ohio, at Milwaukee, Wis., and at Glens Falls and other points in the State of New York. While the rocks occurring at these different points are not identical, either in geological age or in chemical composition, they are in many respects similar. In geologic age they are of carboniferous age or older and in chemical composition they consist of limestones in which clay occurs, either uniformly disseminated throughout the rock, forming a very intimate admixture, or else interstratified with the layers of limestone, so that when the rock is broken up and burned, the resulting mixture of the constituents of the rock is very intimate. Yet intimate as the mixture is, both before and after burning and grinding, in all the ledges the rock has to be sorted and mixed in the same quarry with the greatest care, in order to insure a uniform product from the same works. From the different localities the output is sufficiently different to give the Louisville, Milwaukee and other brands distinctive, though unimportant, characteristics.

At all the natural cement works substantially the same method of manufacture is followed, although the details are modified to suit different localities.

One of the most extensive natural cement plants in the country is that of the Milwaukee Cement Co., at Milwaukee, Wis., the officers of which have kindly furnished the accompanying illustrations. Fig. 1 shows the tramway approaches to the kilns, which are arranged in a double set of ten each. The rock is quarried in the immediate neighborhood and is run in tram-cars, which are seen in the middle foreground, up the inclines to the top of the kilns into which the rock is thrown. The trestle on the right is the dump for coal, which is also loaded into tram cars, one of which is seen at the chute, and run up the incline to the kilns. The rock and fuel are thus conveniently supplied to the kilns at the top, while the burned cement is removed from the kilns at the bottom. Fig. 2 shows one of the kilns on the left; the grinding and shipping house in the center, with the inclines up which the burned cement is hauled and the railroad tracks over which the cement is shipped in all directions from Milwaukee. Fig. 3 represents the grate at the bottom of the kiln, from which the burned cement is removed, while fresh rock and fuel are supplied at the top, thus making the action of the kilns continuous.

Two obstacles make it impossible to prepare a theoretically perfect cement from the natural rock. The first is a lack of uniformity in the rock itself as it occurs in the quarry. This difficulty is obviated as nearly as is possible by careful sorting, by which the least desirable rock

FIG. 2. INCLINES ENTERING GRINDING HOUSE AND TRACKS CONNECTING WITH ALL RAILROADS ENTERING MILWAUKEE.

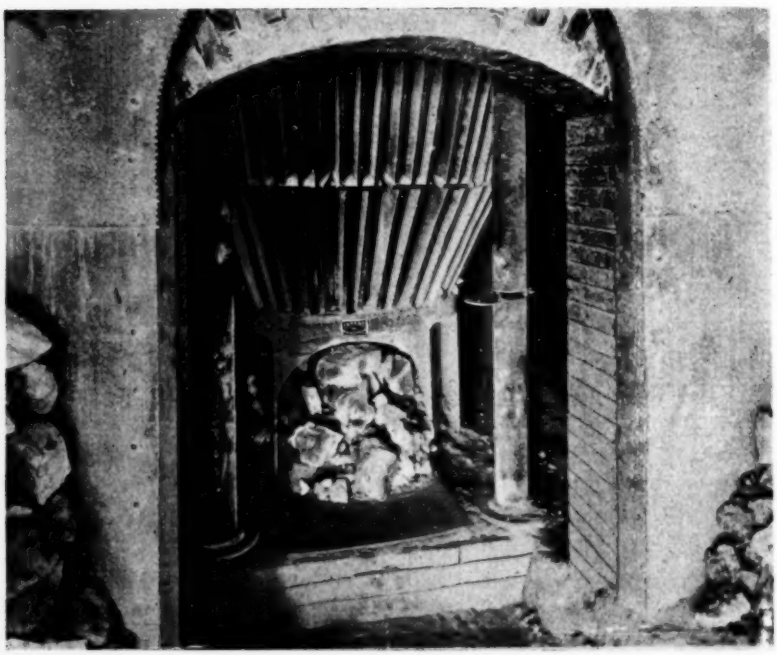


FIG. 3. BOTTOM OF KILN, CAMPBELL PATENT, SHOWING CALCINED MATERIAL.

is rejected and the varied masses selected are carefully mixed so as to ensure a uniform grade. The second is the difficulty of burning the rock in kilns and in large masses so uniformly as to ensure complete burning and no considerable amount of overburning. If natural cement rock is overburned or fused, it becomes a slag, and loses its hydraulic properties. It is not surprising, therefore, that a considerable lack of uniformity exists in the quality of the natural cement found upon the market. The best of them contain a considerable amount of impurity, or material that is not cement, that exists in the rock before it is burned, and also a considerable amount of unburned rock, which together serve to dilute the cement proper, as if a certain amount of sand had already been added to the cement before it is used. These impurities that are inherent in the nature of the materials from which the natural cement is made and also in the process of manufacture that is of necessity followed, result in a cement that can be made and sold at a less price than Portland cement and that is inferior to it for many purposes, while, on the other hand, for a great many purposes natural cements have been found to answer every requirement and are made and used in enormous quantities.

For Portland cements, either a very pure natural limestone or marl is selected and brought into a very finely pulverized condition. Limestones are selected as free as possible from every impurity except clay. Magnesia is never absent, and at best is an inert impurity, but the amount present should not exceed five per cent. Marl is frequently used and is generally purer than limestone. In England chalk is generally used. In Germany chalk and a limestone, locally known as 'mergel,' which is soft and contains clay, are employed.

The following table, No. I., taken from 'Cement Industry,' page 12, gives the composition of the carbonate of lime in use in some of the leading Portland cement manufactories in the United States:

TABLE I.

Limestones and Marls.	Chalk, England, (Reed).	Cement Rock, La Salle, Ills.	Cement Rock, Phillipsburg, N. J.	Cement Rock, Siegfried, Penna.	Marl, Sandusky, Ohio.	Marl, Syracuse, Ind.
Calcium carbonate...	98.57	88.16	70.10	68.91	91.77	88.49
Magnesium "	0.38	1.78	3.96	4.28	0.53	2.71
Calcium sulphate.....					3.19	1.58
Silica	0.64	8.20	15.05	17.32	0.22	1.78
Alumina.....	0.16	1.00	9.02	7.07	1.22	0.91
Iron oxide.....	0.08	0.30	1.27	2.04	0.40	0.30

The clay should be highly siliceous, but should be free from grains of sand. Clays containing carbonate of lime or marl are softer and more easily mixed with the other materials. Clays containing 70%, or more, of silica stand firing without fusing, produce a clinker that

is easy to grind and yield a cement that sets slowly and gains strength over a long period. On the contrary, highly aluminous clays give a fusible clinker and quick-setting cement. A high authority states that the percentage of silica in the clay should be three times the percentages of the alumina and iron taken together. The less iron the clay and limestone contains the lighter colored will be the cement.

The following table, No. II., also taken from 'Cement Industry,' page 13, gives the composition of the clays in use in several Portland cement manufactories:

TABLE II.

Clays.	Medway, England.	Harper, Ohio.	Sandusky, Ohio.	La Salle, Ills.
Silica	70.56	51.50	65.41	54.30
Alumina	14.52	13.23	16.54	19.33
Iron oxide	3.06	3.30	6.06	5.57
Lime	4.43	11.52	2.22	3.29
Magnesia		3.45	1.88	2.57
Carbonic acid	3.48	12.85		
Alkalies	3.95			

A large part of the Portland cement manufactured in the United States is made from natural cement rock, that is, from a rock that contains both the carbonate of lime and clay, very intimately mixed in a natural rock. The best cements, however, are made from an artificial mixture of either limestone or marl and clay. The proportions are determined after very careful chemical analysis in such manner that the several ingredients that form cement shall not only be free from harmful substances, but shall combine to produce theoretical chemical compounds in certain quantitative relations.

Although much has been written for many years concerning the chemistry of hydraulic cements, it is only within about 25 years that researches have been conducted in such a manner that by constructing the compounds possessing hydraulic properties from pure elementary materials, much light has been thrown upon the problem. The French chemist Vicat suggested an 'hydraulic index' to designate the hydraulic properties of different cements, which is a figure representing the number of parts of silica and alumina combined with 100 parts of lime and magnesia.

In 1872 Erdmenger showed that in commercial Portland cements the ratio of lime to the acid constituents, silica, alumina and iron oxide taken together, averaged 1.9. At about the same date, Michaelis determined the ratio, as between 1.8 and 2.2, and called it the 'hydraulic modulus.' These ratios no longer represent the composition of Portland cements as with improved methods of manufacture the proportion of lime has steadily increased, until the 'hydraulic modulus' is no longer applicable to the varying conditions and materials under which the cements are now manufactured.

Since 1890 great progress has been made in the United States in the application of theoretical and scientific principles to the technology of Portland cements, and the result has been an enormous expansion of the business with an improved quality of the product.

The original method pursued in England, and largely adopted elsewhere, was to grind the materials very wet, floating off the fine particles to a large tank where they were allowed to settle. The settling and drying required a great deal of time. This method was followed by a dry process in which the materials were ground together dry and then moistened sufficiently to be molded into briquettes. The briquettes were then dried and stacked in a kiln and burned. The introduction of rotary kilns rendered the molding and drying unnecessary as either dry or wet materials, as a dry powder or wet mud are fed directly to the kilns. The composition of the materials, whether it

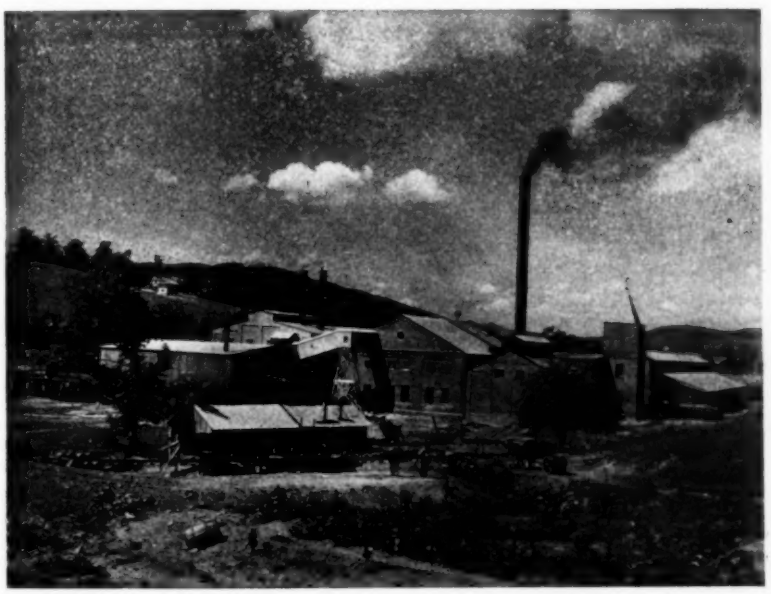


FIG. 4. GENERAL VIEW OF WORKS OF VIRGINIA PORTLAND CEMENT COMPANY, CRAIGSVILLE AUGUSTA CO., VA.

be cement rock or mixed materials, must be maintained by constant chemical analysis, as the percentage of carbonate of lime should not vary by more than ½ per cent. from that found correct for the other materials used.

From the foregoing statements it will be observed that two quite different methods of manufacture are followed. In the first the cement 'mix' is molded into briquettes, which are dried, stacked in a kiln and burned. For the burning by this method three different forms of kiln

are used: 1. The intermittent dome kilns that resemble in their operation common lime kilns. 2. Continuous kilns, of the Ditzsch or Schœfer patterns. 3. The Hoffman ring-kiln. These kilns are economical in fuel, but expensive in time and labor. The dome-kiln was the first used, but has now disappeared from the United States, and survives in Europe only in a few localities. The continuous kilns require highly skilled labor, and are used only to a limited extent either in the United States or Europe. The Hoffman ring-kiln is widely used in Europe, but has found few patrons in the United States.

The second method of manufacture of Portland cement is by the use of the rotary furnace, into which the mix is fed as a dry powder or as a wet mud. Although the rotary cement furnace was originally patented in England, by Frederic Ransome, in 1885, it has been improved in the United States to such an extent that it has become prac-

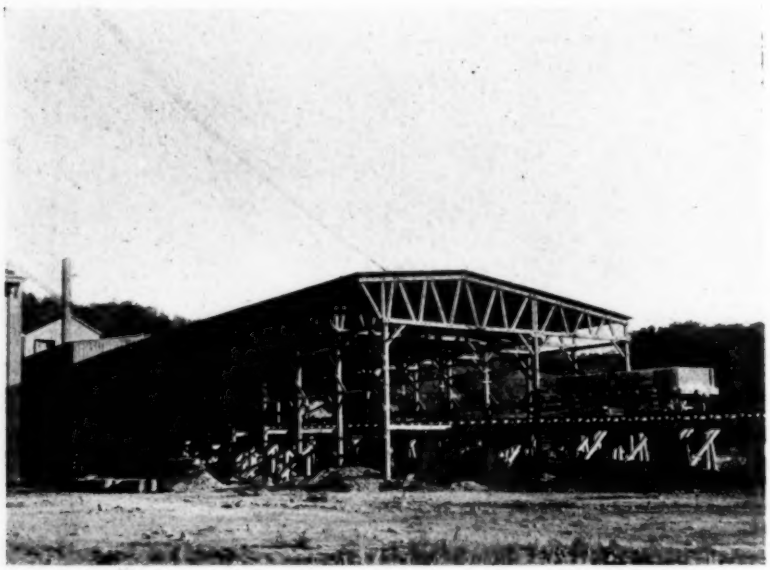


FIG. 5. STONE HOUSE WHERE MATERIALS ARE SORTED.

tically an American invention. Ransome's patent required the use of gas for fuel and the first rotary kilns installed in the United States required gas, but gas was soon replaced by crude petroleum. This fuel took the place of gas entirely, and was exclusively used until it was replaced by pulverized coal, blown into the kilns and burned in a jet like gas or sprayed petroleum. The current or blast of air which carries the powdered coal into the kiln furnishes the oxygen for its complete combustion. This is a convenient method for burning the cheapest fuel on the market, and while it is not economical of fuel it

is very economical of labor and is very uniform in its action, which is an extremely desirable condition in the cement industry.

I am indebted to the obliging courtesy of the officers of the Virginia Portland Cement Co., of Craigsville, Augusta Co., Va., for the accompanying illustrations of a Portland Cement Plant.

Fig. 4 is a general view of the works, which it will be seen at once are very unlike the natural cement works, at Milwaukee. All the operations of a Portland cement works are under cover. Fig. 5 represents

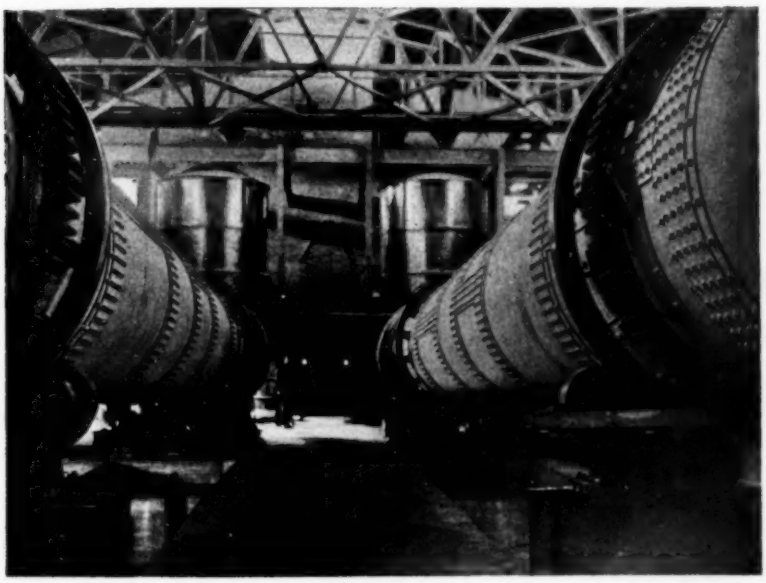


FIG. 6. ROTARY KILNS.

the stone house where the materials are received and sorted, preparatory to being finely ground. A great variety of mills are used for grinding both the crude materials and the cement clinker. So far as the making of the cement is concerned, it does not matter in what kind of a mill the ingredients may be ground, provided they be ground fine and thoroughly mixed in the right proportions. If the mixture is burned dry, the mixing is accomplished by the use of screens and sieves; if it is burned wet, the grinding is done in a wet mill, the paste being floated off and allowed to settle in large tanks. The dry materials are blown into the kiln. The wet mud is allowed to drip into the upper end of the kiln as it is forced in by a pump.

Fig. 6 represents the rotary kiln. It consists of a slightly inclined steel cylinder, about 60 feet in length and 6 to 7 feet in diameter, lined with fire-brick, and revolving by means of powerful gears at the

rate of one revolution in from one to three minutes. Fig. 7 shows the arrangement of apparatus for injecting at the center of the kiln an air blast which carries with it the powdered coal, received from the hopper shown on the right. The rotation of the kiln keeps the 'mix' in constant motion as it passes through the kiln, when it is first dried, then deprived of its carbonic acid and then vitrified or partially fused in such manner as to insure the proper chemical reaction between the basic lime and the acid silica, alumina and iron. Only that skill that is determined by experience can direct the burning at such a temperature that the continuous operation of the kilns will result in a clinker that is neither underburned nor overburned.

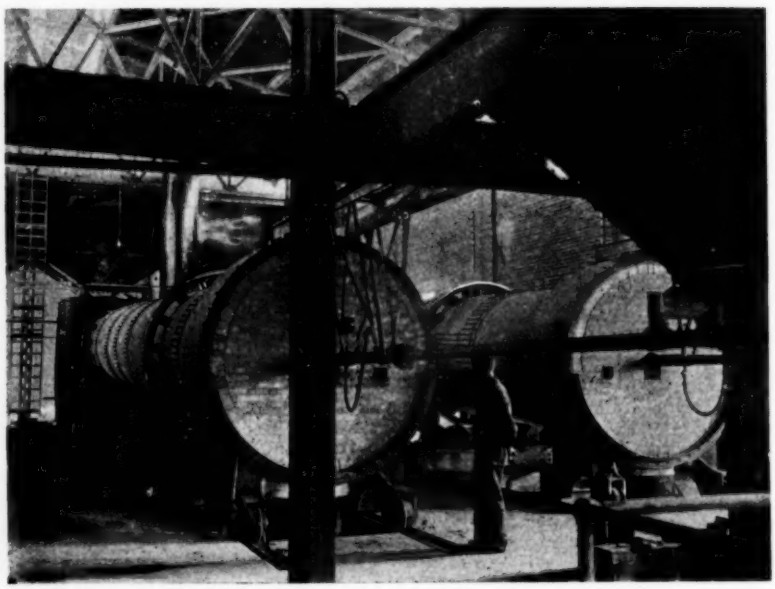


FIG. 7. APPARATUS FOR FEEDING COAL TO KILNS.

So far as the chemistry of cement burning is understood, it appears that at a red heat the water is expelled from the clay; the carbonic acid is then driven from the lime, and it escapes. The silica, alumina and iron of the clay then combine with the lime, first forming fusible glasses and then taking on more lime; at length the tri-calcium silicate informed with the alumina and iron as calcium alumino-ferrite.

Properly burned clinker is in hard rounded grains about the size of dried peas and of a greenish-black color. If it is underburned, it is light colored and soft. If it is overburned it becomes like slag. If it is burned too long, it falls to powder on cooling. Uneven burning is more common in vertical than in rotary kilns, hence the product of rotary kilns is more uniform, ensuring a better cement as the burning

is performed quickly and is quickly arrested when the process is completed.

Experience has proved that the burning of cement is an important factor in its manufacture as determining its qualities. A cement that is properly proportioned, thoroughly mixed and well burned and finely ground will set in about two hours after mixing with water, will harden well after setting and will continue to harden through long periods, even to several years. Ground gypsum is frequently added to cement to control the setting.

Cement should be finely ground. Ninety-two to ninety-three per cent. should pass a sieve of 100 meshes to the linear inch.

Until within the last decade, the Portland cements manufactured in the United States were generally inferior to the best English, German, Belgian and French brands. While these foreign cements have been maintained with the highest degree of excellence the American brands have been greatly improved until at the present time there are no better cements made anywhere in the world than in the United States.

THE INFLUENCE OF RAINFALL ON COMMERCE AND POLITICS.

By H. HELM CLAYTON,

BLUE HILL METEOROLOGICAL OBSERVATORY.

THE causes which control human life and human actions are complex and difficult to grasp; yet, to act reasonably and to progress, man must somehow unravel the tangle of causes and assign to each its true value.

Perhaps, in no department of life are the causes assigned for certain results more varied than in politics. Yet every man with a sense of duty toward his nation feels that he must accept some of the suggested causes as the proper ones, in order that he may form the ideals which guide his actions.

The causes popularly assigned for political and economic changes are almost universally those arising from human actions. A high tariff is assumed as sufficient cause for business prosperity by one class of thinkers, and by another class is assumed to tend toward financial distress. The threat of a silver standard in monetary affairs is considered by one party as a sufficient cause for tremendous business disturbances. With equal certainty these disturbances are considered by another party to be due to the gold standard. Even the success at the polls of a certain political party is assumed by some to be a sufficient cause for general prosperity. One well-known senator has maintained his ability to show, notwithstanding the various phases of opinion through which each of the large political parties has passed, that the success of one particular party at the polls has always been followed by prosperity in the nation, while an opposite result has followed the election of the other party.

It is not my object, nor is it possible for me here, to collect and weigh the evidence which has been given for each of these opinions. My object is to show that, besides those mentioned, there are other forces which act on man in his business and political relations, and that no satisfactory opinion can be formed as to the relative importance of the various causes until these also are considered.

As a professional investigator in science, I am frequently brought to consider the tremendous influences that natural phenomena in the earth, air and sky have on human affairs, and to wonder that these in-

fluences on man's political and business relations are not more frequently considered.

One of the fundamental needs of man, in fact a prime necessity, is a sufficient food supply. When food is abundant and hunger is satisfied there is a surplus of energy to expend on other human affairs, and this, I presume, most people will admit is the primary condition of prosperity.

The food-supply at present is obtained almost entirely from the soil, and its growth is intimately dependent on weather conditions. The relation of the food-supply to the weather has been investigated to some extent, and it is found that the factors which most powerfully influence the food-product are temperature and moisture, which latter is derived from rainfall. The annual change in temperature is comparatively regular and certain, so that the factor which, by its changes, most powerfully influences the food-product, is the rainfall.

J. T. Wills investigated the relation of the rainfall to the wheat-product per acre in south Australia for the six winter months (the growing season there), and found that for the seven best years there was a yield of 12.4 bushels of wheat with 18.5 inches of rain; for the next best years there were 10.0 bushels of wheat with 15.4 inches of rain; and for the six worst years there were 6.6 bushels of wheat with 13.5 inches of rain. The product of wheat in the first case was nearly twice as great as in the last. If such a relation holds for the United States, it is easy to understand what great effect a general drought may have on the food product. If the amount of wheat raised in the United State were reduced one half or even one third by a year of deficient rainfall, it is easy to imagine an enormous strain on the business of the country, and with a succession of such years the effect might mean disaster. Such a deficiency in the wheat supply, with wheat at 80 cents a bushel, would mean for a single year a direct loss in wealth of more than $100,000,000; it would mean that nearly all the wheat which is usually shipped abroad would be needed at home; it would mean that thousands of railroad cars and ships which ordinarily transport this grain would lie idle; that hundreds of men who usually handle this grain in transport would be out of employment; that farmers in large numbers would be unable to meet their obligations; and consequently, that banks and business of all kinds would suffer.

But the deficiency in rainfall would not affect the wheat alone; every product of the soil would likewise suffer. Rawson has worked out a simple formula in the case of Barbadoes by means of which the amount of sugar to be exported the next year can be calculated with great accuracy from the rainfall of the current year. This calculation is accurate within six per cent. in most cases. Similar calculations for Jamaica have been made by Maxwell Hall. He shows that 56 inches of

rain give 1,441 casks of sugar per acre, while 79 inches give 1,559, or about one-tenth more. This means an increase in the value of the sugar-crop alone of £100,000.

District.	Rainfall, inches.	Sheep per sq. mile.	Increased capacity for every inch of rain.
South Australia.....	8 to 10	8 to 9	1 sheep per mile.
New South Wales (1).....	13	96	22
New South Wales (2).....	20	640	70
Buenos Ayres.....	34	2630	140

Nor is the influence of rainfall on vegetable life alone to be considered, as is evident from the following data gathered by Wills con-

TABLE COMPARING RAINFALLS, WATER-LEVELS AND COMMERCIAL CRISES.

Dates.	Departure from Normal.			Commercial Crises.	Dates.	Departure from Normal.			Commercial Crises.
	Rainfall in the Ohio Valley (inches).	Rainfall in the Miss. Valley (inches).	Level of Lake Mich. (feet).			Rainfall in the Ohio Valley (inches).	Rainfall in the Miss. Valley (inches).	Level of Lake Mich. (feet).	
1830	+2.0	.....	.....		1864	—0.3	—2.5	— .08	
1831	+5.1	.....	.....		1865	+3.0	—1.4	— .32	
1832	+1.9	.....	.....		1866	+4.0	—0.7	— .65	
1833	—1.9	.....	.....		1867	+1.6	—0.6	— .21	
1834	—6.1	.....	.....		1868	+1.1	+0.9	— .70	
1835	—6.8	.....	.....		1869	—1.1	+0.7	— .58	
1836	—4.5	.....	.....		1870	—4.7	—2.1	+ .33	
1837	—0.4	.....	.....	Panic	1871	—7.2	—3.2	+ .26	
1838	—3.3	.....	.....		1872	—6.0	—2.7	—1.02	
1839	—4.5	.....	.....		1873	—2 7	—3.2	— .37	Panic
1840	—2.1	.....	.....		1874	—0.5	—2.6	+ .12	
1841	+0.8	.....	.....		1875	+0.5	+1.5	— .13	
1842	+2.2	.....	.....		1876	—0.3	+5.5	+1.00	
1843	+2.1	.....	.....		1877	—2.8	+5.2	+ .77	
1844	+0.9	.....	.....		1878	—3.2	+2 1	+ .46	
1845	+1.9	.....	.....		1879	—0.3	+1.4	— .46	
1846	+6.0	.....	.....		1880	+3.4	+4.0	— .32	
1847	+8.3	.....	.....		1881	+6.4	+6.1	+ .20	
1848	+7.6	+ 6.8	.....		1882	+8.0	+5.4	+ .57	
1849	+6.6	+15.6	.....		1883	+6.0	+3.9	+ .72	
1850	+4.7	+22.8	.....		1884	+1.0	+2.7	+ .82	
1851	+1.3	+26.4	.....		1885	—2.4	+0.4	+1.07	
1852	—0.8	+21.5	.....		1886	—2.8	—1.8	+1.31	
1853	0.0	+ 9.0	.....		1887	—1.5	—3.4	+ .67	
1854	—0.4	— 1.0	.....		1888	+0.4	—3.1	+ .06	
1855	—1.0	— 2.2	.....		1889	+2.9	—3.0	— .49	
1856	—2.4	+ 2.1	.....		1890	+3 9	—2.5	— .40	
1857	+0.5	+ 5.2	.....	Panic	1891	+1.9	—1.4	—1.16	
1858	+4.9	+ 5.3	.....		1892	—1.7	—1.0	—1.27	
1859	+4.2	+ 2.2	.....		1893	—4.7	—2.8	— .99	Panic
1860	+0.9	— 0.1	+1.07		1894	—7.4	—5.2	— .87	
1861	—0.5	+ 2.4	+1.05		1895	—8.1	—6.0	—1.91	
1862	—1.2	+ 3.5	+1.01		1896	—6.4	—5.2	.....	
1863	—2.1	0.0	+0.54		1897	.....	.....	.....	

cerning the number of sheep which can be pastured per square mile with different rainfalls.*

Such investigations have not been made for the United States, but the data indicate clearly the enormous variations in the food-supply, both vegetable and animal, which attend variations in rainfall; and they suggest how these variations must affect the producer, the transporter, the merchant and the consumer. Hence it is easy to imagine the great influence which variations in rainfall may have on commerce and through this on politics.

The accompanying table gives the variations in the amount of rainfall in the Ohio Valley and in the Mississippi Valley which lie about the center of the food-producing area in the United States and include a large part of this area. The data are derived from tables prepared by Professor A. J. Henry, of the United States Weather Bureau, and published by the Bureau as Bulletin 'D,' entitled 'Rainfall of the United States,' Washington, 1897. The average rainfall for each district was made up from a number of stations in the district, the same stations being used so far as the records would permit throughout the period 1830 to 1896. The sharp, irregular fluctuations which characterize the rainfall were toned down by Professor Henry by taking the means of several successive years. This process is called 'smoothing' and it renders more evident the long-period oscillations. The average rainfall for each district was obtained, and the departures of the rainfall for each year from this mean are given in the accompanying table. The plus sign indicates that the rainfall for the given year was above the mean, and the minus sign that it was below. The figures give the amounts in inches and tenths of inches. The figures for the Mississippi Valley from 1848 to 1857 are derived from the observations at one station only.†

The table also gives the departures from the mean value of the level of the water in Lake Michigan. These data have been carefully collected by the engineers on the lakes and were kindly furnished by General John M. Wilson, Chief of Engineers, U. S. Army. The figures show, in feet, the departures of the annual means from the general average. The lake may be regarded as an enormous rain-gauge. When the rainfall is in excess, the water level rises above the mean; but

* These facts are largely derived from Hann's 'Climatology,' a standard work on climate. (See Ward's English Translation.)

† Professor Henry also gives the rainfall for New England. Although the oscillations run roughly parallel to those in the interior valleys the data are not reproduced here, (1) because Mr. E. B. Weston has shown that the early measurements are probably deficient on account of the methods of measuring the snowfall; (2) because New England has largely ceased to be an agricultural region.

during droughts evaporation exceeds the supply, and the level falls below the mean. Alongside of these data are indicated the dates of the severe financial panics in the United States. The dates of these panics were taken from one of the current histories of the United States.

The table shows that the observations in the Ohio Valley began during a period when the rainfall exceeded the average amount. This lasted through 1832, after which a severe drought set in, lasting until 1840. The severe financial panic of 1837 occurred in the midst of this drought and about two years after the greatest deficiency of rainfall in the Ohio Valley. The rainfall statistics for New England show that there was also a very severe and protracted drought in the eastern states at that time, culminating in 1836 to 1837, when the annual rainfall was nearly nine inches below the normal. In 1841 began a period of excess in rainfall lasting until 1853, after which a period of drought set in, culminating in 1855 in the Mississippi Valley, and in 1856 in the Ohio Valley. This was followed by the severe financial panic of 1857. This was in turn followed by another period of excess in rainfall, lasting until 1860 in the Ohio Valley, and until 1862 in the Mississippi Valley, when another period of deficient rainfall set in with the greatest deficiency in 1863 and 1864. Any commercial effect attending this drought was overshadowed by the tremendous disturbances in the life of our country attending the civil war. Another period of excessive rainfall occurred between 1866 and 1869, followed by a severe drought which reached its maximum in the Ohio Valley and Mississippi Valley in 1871, and in the Lake Region in 1872. This was followed by the severe panic of 1873. This in turn was followed by another period of excessive rainfall which began in the Mississippi Valley in 1875, in the Lake Region in 1876 and in the Ohio Valley in 1879 and lasted until between 1884 and 1887. This was accompanied and followed by a period of unusual business activity and enterprise, especially in our western states. With 1887 began a long and severe drought, lasting nearly ten years and reaching its maximum severity in 1895. During this interval the United States was well covered by observing stations and permitted Professor Henry to make an investigation of the deficiency of rainfall for the entire United States. He says, in speaking of this interval, 1887 to 1896, "It appears beyond question that there has been a very general deficiency of rain in the great majority of the years and in almost all the districts. Moreover, there does not seem to be any law of compensation by which a deficit in one district is balanced by a surplus in another. The South Atlantic and Gulf States, in particular, show a marked deficit throughout almost the entire period." This drought was relieved in some sections about 1889 to 1891, as in the Ohio Valley, by an excess of rainfall for two or three years. In the midst of this drought

occurred the severe financial panic of 1893 to 1894. This panic occurred one or two years before the greatest deficiency of rainfall and thus differed from the preceding panics which occurred one or two years after the greatest deficiency. But a very marked depression in business activity continued throughout the interval 1893 to 1897 inclusive.

It is thus evident that every severe financial panic has been closely associated with a protracted period of deficient rainfall, and there has been no period of protracted drought without a severe financial panic except a period, the effects of which were masked by the large disturbances attending our civil war. Hence, it is difficult to avoid the conviction that periods of deficient rainfall are the paramount causes of the periods of commercial distress, especially when the means by which the two are connected are so reasonable.

As another link in the chain of causation, it is interesting to trace the coincidences between the periods of deficient rainfall, deficient food supply and financial panics and the subsequent changes in political life.

Concerning the panic of 1837, I quote the following from a current history, "The panic of 1837 was a severe blow to Van Buren and his party. A slight return of the panic in 1839 completed the work; and though his party stood manfully by him and renominated him for the presidency, he was defeated by the Whigs . . . like Jackson, on a wave of enthusiasm, 'Tippecanoe and Tyler too' were triumphantly elected."*

In the presidential election following the financial panic of 1857, that of 1860, the Democratic party which had previously been in power was disorganized and broken into factions, and the new Republican party sprang triumphantly into power. However, it is probable that the great issue of slavery had a large share in these occurrences.

The first national election after the financial panic of 1873 was that of 1874, when the Republican majority of 107 in the House of Representatives was turned into a Democratic majority of 74, and two years later the Democratic party failed in obtaining the presidency only by the narrowest margin, although the country at the previous presidential election had been overwhelmingly Republican.

The political effects following the commercial crisis of 1893 to 1894 were very striking. The Democrats who were then in power, realizing that they were held responsible for the commercial distress, abandoned every important issue for which they had previously stood, and, even repudiating their former leader and his opinions, nominated a new leader, the champion of a new issue. But this in no way saved them from overwhelming defeat at the next election. The marked disturb-

* 'A History of the United States' by Allen C. Thomas, Boston, 1899.

ances in civil life following the commercial panic of 1893 was shown by the 'Coxey army of 1894' and the Chicago riots.

It is interesting to read the various causes given for financial panics and political upheavals even by historians. In 1837, the cause was said to be the State Banks. In 1857, it was the too rapid railroad expansion. In 1873, it was the reaction from the lavish expenditures attending the civil war and the contraction of the currency. In 1893, it was the low tariff and the 'free silver craze.' All of these may have been contributory causes, but if my assumption is correct that deficiency of rainfall is the paramount cause in this chain of events, then vast political and historical changes have been brought about, and the thoughts of men have been swayed by opinions which are akin to superstitions, because they attribute to human action what is due largely to natural causes beyond the control of man.

The recent period of financial distress (1893-97) in the United States was also a period of financial distress in Europe. This may have been due to the fact that Europe depends to a large extent on the United States for its food supply; or to the fact (which recent observations seem to indicate) that long periods of drought and excessive rainfall embrace a large part of the world, if not the whole world, in their operations, and are due perhaps to changes taking place in the sun.

The following extract from an American newspaper reprinted in the English periodical 'Nature,' 1895 (Vol. 53, p. 78), shows that severe droughts in other parts of the world were coincident with the one in the United States:

> The long drought, which has caused so much inconvenience and damage this fall, seems to have prevailed all round the world, if not in every part of it. Europe has experienced it almost equally with this country, and in Australia it has been more severe than here. So great was the distress in New South Wales, that the Government appointed a Sunday in September as a day of prayer for rain, and special services in accord with the proclamation were held in all the churches of every denomination in Sydney and throughout the province. The drought occurred in the antipodean spring, and greatly retarded planting operations, as well as doing great general damage. In many districts the grass was literally burned off the earth, and the mortality among stock was great. The railway trains carried supplies of water from lakes and rivers to all stricken points along the lines, selling it at the rate of 25 cents a thousand gallons. The water supply of many towns entirely failed, the inconvenience experienced was acute everywhere, and many agriculturists were ruined.

The existence of this drought is confirmed by recent meteorological reports from Australia. (See 'Science' of January 11, 1901, p. 75. A note concerning a simultaneous drought in Great Britain is found in 'Nature,' 1895, Vol. 52, p. 597.). These years were followed by rapid changes in political parties in Europe, especially in Great Britain and France.

On the other hand, the parties which are in power, when the increased rainfall and subsequent prosperity reappear, claim and get the credit for it, and are usually returned to power by large majorities. In France, the present ministry has been in power for several years; in England, the conservatives have been returned with immense majorities; in Canada, the liberals were equally successful; and in our own country, the republicans were returned on a 'tidal wave.'

To designate as a superstition the belief in the capacity of the various political parties in power to make prosperity may be extreme, but certainly careful thinkers will join in the wish that such relations to natural phenomena as are here outlined might be carefully studied by trained investigators, using well-known scientific methods. Perhaps, then a unity of belief as to the causes of commercial distress might be obtained equaling that which has prevailed since Darwin's day as to the causes of variety and changes of form in the animal kingdom.

Would that some wise benefactor would found an institution purely for research, where all such questions of man's relation to the universe could be carefully investigated by trained investigators using the well-tried and fruitful methods of science!

Such an institution should be perfectly free and independent of the control of any other institution or party and especially should it be free from Government control. No man should be appointed to it because he believes in certain current theories, as, for example, free trade, and would give free trade statistics while the free trade party was in power, only to be dismissed and replaced by a man who would give high tariff statistics while the high tariff party was in power. His loyalty should be to the truth alone, and he should be allowed perfect freedom of expression for his results and conclusions, however much they might differ from accepted beliefs.

Such an institution, with an adequate endowment, devoted without let or hindrance to the search for truth in every field of human activity, would be of inestimable value to the nation.

Our universities, performing the threefold functions of training in methods, diffusing knowledge and investigating the laws of nature, are undoubtedly an immense power for progress in the nation. But they have strangely neglected the atmosphere and its relations to man. In only one university of our nation is there a professorship of climatology, and that of so recent a date as to be almost of the present. Is it any wonder that the influence of our atmosphere on health, commerce and politics is so little known? The work in meteorology in America heretofore has been almost entirely outside of our universities; but surely this cannot last. Our universities should somehow find means to give the study and teaching of meteorology their rightful and independent places.

LUCRETIUS AND THE EVOLUTION IDEA.

By Professor WILLIAM L. POTEAT, M.A.,
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Felix, qui potuit rerum cognoscere causas,
atque metus omnes et inexorabile fatum
subiecit strepitumque Acherontis avari.
—Virgil, Georg. II. 490–492.

It seem'd
A void was made in Nature; all her bonds
Crack'd; and I saw the flaring atom streams
And torrents of her myriad universe,
Ruining along the illimitable inane,
Fly on to clash together again, and make
Another and another frame of things
Forever: that was mine, my dream, I knew it.
—Tennyson, Lucretius.

Lucretius, nobler than his mood,
Who dropped his plummet down the broad,
Deep universe, and said, 'No God,'

Finding no bottom: he denied
Divinely the divine, and died
Chief poet on the Tiber-side

By grace of God: His face is stern
As one compelled, in spite of scorn,
To teach a truth he would not learn.
—Mrs. Browning, A Vision of Poets.

IN the essay on Dante, Macaulay reproached the English poets with the tendency then showing itself among them to consider the objects and phases of external nature fit material for the exercise of their art. The reproach arose in part out of the fancied antagonism between poetry and science, and it has been often echoed since that day by poets as well as critics.

The judgment is a shallow one. Poetry is, indeed, imaginative. Whatever else it may have or want, it ceases to be poetry when the glow of imagination fades out of it. Science, on the other hand, occupies itself with fact only, with things as they are observed to be, not as they are imagined to be. But imagination and observation are not at war with each other. Distinction is not opposition. And, besides, the poet's constructive imagination is helpless without the materials supplied by observation; and the scientist's observation is aimless and unfruitful without the stimulus and guidance of imagination.

But a simpler and perhaps more decisive proof of the near and hospitable relations of poetry and science is presented in the cases of their actual union in the same person. When imagination ceases to be mistress and becomes servant to observation, your poet turns scientist. When observation yields the scepter to imagination, your scientist turns poet. The names of Maxwell, Tyndall, Romanes and Huxley suggest themselves as examples of scientists of the first rank whose poetic gift is manifest in their published poems. Of the poets of the first rank who have shown the scientific turn and interest, one thinks first of Tennyson. He studied medicine until he imagined that he had all the diseases set out in the books. His interest in astronomy he maintained to the time of the 'twilight and evening star.' From his student days at Cambridge when 'the fairy tales of science' first won him, even down to the 'Locksley Hall Sixty Years After,' he meditated deeply on evolution. The scientists of his period looked upon him as their most intelligent mouthpiece in the world of letters. Goethe, it is well known, felt more satisfaction in his scientific achievements than in the poems which made him the chief figure in German literature. It was a comparatively small thing to have written 'Faust,' but to be the only person of his century who understood the science of colors—that was a thing to be proud of.

Classic, as well as modern, literature offers illustrations of the union of the poetic and the scientific interest. There are some extant lines of Virgil headed, 'Virgil abandons other studies and embraces the Epicurean Philosophy.' That this love of science—for ancient philosophy included science—was no transient passion is attested by poems on natural objects and by passages in the Georgics, the Eclogues and the Æneid. His last fatal journey to Greece and Asia was undertaken in order that he might complete the Æneid, and then devote the remainder of his life to science. But in all the history of literature, the best example of the fellowship of science and poetry is Lucretius, the poet in whom we are here particularly interested; for he was not at one time poet and at another time scientist, but rather both at once. It is Mrs. Browning's judgment that Lucretius 'died chief poet on the Tiber-side,' and a *Quarterly Reviewer* has recently declared him to be Rome's truest man of science. But such eminence in the two spheres is paralleled in the case of Goethe. What makes the work of Lucretius quite unique is the fact that his first-rate poetic capacity cooperates with his capacity for science in the same task. The poet's imagination kindles into beauty the scientist's perceptions, and the issue is a poetical treatise on physics and biology, or, if you prefer, a science poem.

It is true that a certain type of mind in the eighteenth century was drawn to Lucretius, recognizing in him a sort of fellowship of

skepticism. But his present vogue dates only from the middle of the nineteenth century, when the great questions which he treated reached again the acute stage of interest. The search into the constitution of matter and the origin and development of living beings, and the sharp antagonisms of science and theology, which have distinguished the past half century, called out of obscurity the poet-scientist who, quite alone, passed over the same path two thousand years before. On account of this kinship of task and attitude Lucretius, to the modern man of science, is better known than any other ancient poet.

Professor Jowett used to say that all that was really known of Shakespeare might be written on half a sheet of note-paper. Of Lucretius very much less is known. Indeed, with the single exception of Homer, there is no considerable writer of antiquity whose personal history is so meager and vague. Two sentences by the Christian Father Jerome and a single sentence by Donatus constitute his extant biography. The statements of Jerome are—that Lucretius was born in the year B. C. 94; that, having been made insane by a love-potion, he wrote, in the intervals of insanity, certain books which Cicero corrected; and that he died by his own hand in the forty-fourth year of his life. Donatus in his 'Life of Virgil' informs us that, on the day when Virgil assumed the toga virilis, Lucretius died. By the help of Donatus we can correct the birth-date given by Jerome, and fix it at about the beginning of B. C. 98. The story of the philtre, insanity and suicide is probably a legend with a historic germ of some unknown tragedy in his life. Upon that legend Tennyson has made his poem of 'Lucretius,' which is a marvel at once of faithful portraiture and of exquisite beauty.

If we turn through the 'De Rerum Natura' in hope of chance self-revelations of the author, we are disappointed. He is almost as impersonal as Shakespeare. He lets fall no fact of his station or fortunes in life. We do, however, discover some of his personal characteristics. Here is an austere and serious student of the problems of nature and of human life and destiny. He is, as he says himself,* not only a philosophical teacher and a poet, but also a moral reformer, and so ardent is his zeal to effect his practical aim of emancipating men from the bonds of superstition that he subordinates to it both his philosophy and his poetic passion. His praise of the tranquil, obscure life suggests that he knew and loved it. We are warranted in inferring that he was the social equal of C. Memmius to whom his poem is addressed and that accordingly he was of the governing class. But we catch hints here and there that the political history of the last years of the Republic only repelled and distressed him, and, having no leaning

* I. 931–934.

to social pleasure, he chose to lead the retired and contemplative life. The Epicurean ethics, which he accepted, produced diverse practical results according to the natures which received it. In shallower natures, like those of Catullus and Horace, it produced an easy-going life of pleasure-seeking; in deeper natures, like Lucretius, Virgil, Epictetus, the same system showed itself in a sincere and strenuous moral life closely akin to that of the Stoics. We may, therefore, accept as historically true and as being well within the suggestions of the poem, the words which Tennyson puts into the mouth of Lucretius:

> I thought I lived securely as yourselves—
> No lewdness, narrowing envy, monkey-spite,
> No madness of ambition, avarice, none:
> No larger feast than under plane or pine
> With neighbors laid along the grass to take
> Only such cups as left us friendly-warm,
> Affirming each his own philosophy—
> Nothing to mar the sober majesties
> Of settled, sweet, Epicurean life.

We discover, moreover, his absolute sincerity and devotion to truth, his large and reverential conception of the sum of things—the *majestas cognita rerum*—his high moral purpose and poetic fervor which sustain him throughout a prolonged and difficult achievement at an unusual elevation of thought and passion. As Professor Sellar remarks, he combines in himself the Greek ardor of speculation and the Roman's firm hold on reality, the theorizing passion of the dawn of science with the minute observation of its meridian.

So far as we know Lucretius left but one work, the 'De Rerum Natura,' *i. e.*, 'The Constitution of Things,' but that single work will, as Ovid prophesied, preserve the memory of his genius until the world disparts in its final catastrophe. Certainly in all the record of literary effort, the poem is unmatched in at least one respect: it is a closely reasoned system of natural philosophy in verse. Tennyson's 'Two Voices' has been mentioned as like it in the wealth of poesy enlisted to beautify abstruse argument. But the subject-matter of that striking poem is different and yields itself more kindly to poetic treatment; it seems, moreover, to be but a short 'swallow-flight of song' beside the sustained elevation and wide sweep of the ancient master. Lucretius had the example of Empedocles for the poetic form of his treatise, but that alone would not have determined his choice. Two other considerations moved him—first, his own poetic impulse, and, second, the wish to make an unfamiliar doctrine attractive; he would overlay it, as he says, with the pleasant honey of the muses.

But the purpose of the poem is not the emulation of the Sicilian poet-philosopher, nor yet the gratification of his own sense for beauty.

He imposes on himself a far graver task. After a pathetic recital of the sacrifice of Iphigenia on the altar of religion by the hand of her father, Lucretius writes the great line of the poem—

Tantum religio potuit suadere malorum—

such are the evils to which religion leads! And he soon adds, "This terror and darkness of mind must be dispelled, not by the rays of the sun and the glittering shafts of day, but by the aspect and law of nature." His lofty aim is no less than the permanent defeat of the ancient reign of superstition by setting forth the new knowledge of nature.

The poem is in six books, which aggregate nearly seven and a half thousand lines. It is not far from three-fourths the length of 'Paradise Lost.' In the first book Lucretius expounds the physics of his great master Epicurus, starting with the fundamental principle that nothing comes from nothing, and the other that all that is is either atoms or space. In the second book he derives all the properties of things from the shapes and concourse of the atoms. The remaining books apply the general principles of the first two to sensation and the doctrine of the soul's immortality, the origin and the final ruin of the mass and fabric of the world, the origin of plants and animals, the rise and development of human civilization, and lastly the explanation of certain terrifying phases of nature, as thunder, earthquake, volcanic eruptions and the plague.

If it be asked, How can this exposition of ancient physics, biology and physical geography be poetry? it must be answered that much of it is not poetry. But the same is true of 'Paradise Lost' or 'The Ring and the Book.' A poem is to be judged, not by the proportion of prosaic content which it carries, nor by successes or infelicities of detail, but by the single impression which it makes considered in its totality. Judged by this standard the poem of Lucretius is one of the world's masterpieces. It becomes all the more remarkable when we recall the limitations under which the poet worked: the language in which he wrote had hitherto been all unused to the music of verse, the exigencies of the exposition of an obscure and prosaic subject-matter dominated the treatment, and the yoke of a practical moral purpose was always on the neck of the poetic impulse.

Of course the value of Lucretius does not lie in his science, and yet our subject demands some consideration of at least one feature of his scientific system. In the first place, he has, amid many puerilities, some curious foreshadowings of modern scientific opinion. The following may be cited: the eternity of matter;[1] the conservation of matter[2] and of force[3]—Haeckel's 'law of substance'; the atomic con-

[1] I. 149, 150. [2] I. 215–266; II. 294–307. [3] II. 294–307.

stitution of matter;[1] the doctrine of films,[2] which recalls Newton's corpuscular theory and the very recent discovery of the 'Becquerel rays'; the relations of waste and repair in youth and age;[3] the inviolability of natural law.[4]

Of special interest to us is a passage in the fifth book[5] which sets forth the ideas of the struggle for existence and natural selection in terms of remarkable clearness for a pre-Darwinian writer. Lucretius even announces them in connection with the domestication of animals, which was the precise point from which Darwin started in his effort to account for 'the origin of species.'

> And many races of living things must have then died out and been unable to beget and continue their breed. For in the case of all things which you see breathing the breath of life, either craft or courage or else speed from the beginning of its existence protected and preserved each particular race. And there are many things which, recommended to us by their useful services, continue to exist consigned to our protection. In the first place, the fierce breed of lions and the savage races their courage has protected, foxes their craft and stags their proneness to flight. But light-sleeping dogs with faithful heart in breast and every kind which is born of the seed of beasts of burden and at the same time the woolly flocks and the horned herds are all consigned, Memmius, to the protection of man. For they have ever fled with eagerness from wild beasts and have ensued peace and plenty of food obtained without their own labor, as we give it in requital of their useful services. But those to whom nature has granted none of these qualities, so that they could neither live by their own means nor perform for us any useful service in return for which we should suffer their kind to feed and be safe under our protection, those, you are to know, would lie exposed as a prey and booty of others, hampered all in their own death-bringing shackles, until nature brought that kind to utter destruction.[6]

In close sequence comes the most interesting portion of the entire poem, the detailed account of the evolution of human society from the rude 'life after the roving fashion of wild beasts' up to the settled security and elegancies of the highest civilization. Noteworthy in this account is the representation of childhood as the first humanizing influence, the origin and growth of language, religious beliefs and social order, the development of industries and of art, until the poet himself appears 'to consign the deeds of men to verse.' Thus, says Lucretius, "time by degrees brings each several thing forth before men's eyes, and reason raises it up into the borders of light; for things must be brought to light one after the other and in due order in the different arts, until these have reached their highest point of development."

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[1] I. 267–328; II. 80–141, 333–477, 660–699.

[2] IV. 29 f.

[3] II. 1118–1147.

[4] V. 55–58.

[5] V. 855–877.

[6] Here, as elsewhere, I have used Munro's translation.

These citations of the evolution idea in Lucretius are a sufficient refutation of the popular notion that somehow Darwin is responsible for the invention of this revolutionary conception. Indeed, the doctrine of evolution is itself one of the best illustrations of the law of evolution, for it has a continuous, progressive history of twenty-five centuries. It stretches the slow process of its rise and development from Thales' 'evolution's morning star,' more than six hundred years before Christ, down to the present hour. The hazy surmises of the early Greek speculation become precise and organic in the teaching of Aristotle, that nature proceeds by gradual transitions from the most imperfect to the most perfect, that the higher species are descended from the lower, that man is the highest point of a long and continuous ascent. The idea thus definitely enunciated by 'the master of those that know,' may be traced through Lucretius to the Christian theologians of the medieval period, and from them to the philosophers and naturalists of the seventeenth and eighteenth centuries. At the beginning of the nineteenth century we meet Lamarck, the most important figure in this history since Aristotle. His 'Zoological Philosophy' (1809) is the first elaborate exposition of the means or factors of evolution as applied to the origin of living forms. From his day the descent of the higher organisms from the lower was a standing question among naturalists until the publication of Charles Darwin's 'Origin of Species' in 1859. That splendid product of a great mind brooding for years on an enormous mass of facts, practically closed the question and won at once the almost unanimous assent of the naturalists of the world.

Our old-world poet not only takes an honorable place in the historical development of scientific opinion, but also illustrates in his own person certain modern phases of the relation between science and religion. He has been called the high-priest of atheism and the apostle of irreligion. He does deny Providence and the future life with great elaboration of argument; he does scout with vehemence the current theology and worship. And this, too, in the name of his scientific system. But was his science atheistic and irreligious? His fierce indignation—does it burn against the gods themselves, or against the popular conception of the gods? Does he despise religion itself, or the 'foul' perversion of it?

Respecting Lucretius' opposition, in the name of science, to religion, it is to be borne in mind that, speaking generally, the Romans had no genius for religion. They were called unto politics, as the Hebrews were called unto religion. The national religion derived what vitality it had from its alliance with the civic spirit, and with the decline of that spirit, religion dropped into cant with a meager and barren ritual and a train of grotesque superstitions. It was at times polluted by

shocking immoralities, and there are hints here and there of human sacrifices. The future life, even when it was allowed, was far from attractive to a noble spirit, being a sort of languid and aimless shadow of the present life. The Roman gods are vague abstractions with no appeal to the imagination or enthusiasm of their votaries, and, so far as they touch human life at all, malevolent and irresistible. This was the body of religious beliefs and practices against which Lucretius protested in the interests of humanity. In doing so, he showed his essentially religious nature. 'He denied divinely the divine.' The divine within him recognized nothing kindred in what was currently called divine, and he invoked the aid of science to dispel 'this terror and darkness of mind.'

SENSORY MECHANISM OF PLANTS.

By D. T. MACDOUGAL,

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THE relation of the vegetal organism to its environment has demanded a much more generalized type of sensory action than that of the animal. Thus but few species of plants have developed special perceptive organs. The sensory functions are exercised by extended regions of the body, yet the delicacy of appreciation of differences in the intensities of external forces is not surpassed by that of the animal. Thus no plant has sensory organs for the reception of light-stimuli, yet, as a matter of regulation of their main function of food-building, leaves react to differences in intensity far beyond the range of the unaided human eye. Special tactile organs are differentiated in tendrils and in certain 'carnivorous' species and 'sensitive' plants,

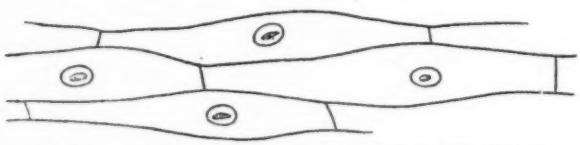

FIG. 1. SURFACE VIEW OF CELLS OF PERCEPTIVE REGION OF THE COLUMNA OF *Stylidium graminifolium*. AFTER HABERLANDT.

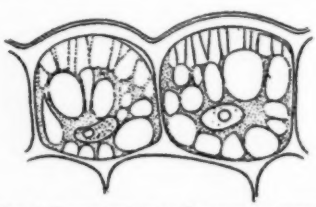

FIG. 2. LONGITUDINAL SECTION THROUGH A SINGLE PAPILLA OF AN EPIDERMAL CELL OF THE COLUMNA OF *Stylidium graminifolium*, WHICH IS SENSITIVE TO CONTACT.

FIG. 3. EPIDERMAL CELL OF THE PERCEPTIVE LAYER OF TENDRIL OF *Entada scandens*.

in which members are adapted to a narrow and unusual non-typical purpose. Here also great delicacy and accuracy is obtained, and the contact or weight of a body inappreciable to the sense of touch of any known higher animal may act as a stimulus. This refinement of reaction in undifferentiated tissues is quite remarkable. As a further instance it may be cited that leaves of certain seedlings are capable of appreciating an intensity of light equal to .00033 of a standard candle.

Very naturally the first studies made in this subject attempted to discover an arrangement in plants comparable to a simplified neuro-muscular system of the animal. Expectations of this character were of course bound to meet with signal disappointment; a fact that should have been apparent if the history and widely different purpose of the animal and vegetal organism had been taken into consideration. Parallelisms between the reactions of plants and animals even to the same class of stimulus are to be accepted with great caution. Thus it has recently become apparent that the heliotropism of animals as investigated by Loeb is widely different from the heliotropism, or phototropism, of plants both as to the features of light acting as stimuli in the separate cases, and the general nature of the consequent reactions.

Recent papers by Nemec on the transmission of impulses in plants, and the discussions of geotropism and the organs of equilibrium of plants by Noll, Czapek and Haberlandt have awakened much interest in the mechanism of irrito-motility of plants.

Not fully appreciating the significance of the diffused and generalized forms of perception organs, much effort has been directed toward fixing on specialized protoplastic tracts, with functions analogous to nerves. The quest has not yet met with decided success in any single instance. We have, however, arrived at the general conclusion that the ectoplasmic layers of the protoplasts of peripheral cells function as sensory organs, and that impulses are transmitted between the motor and sensory zones by these layers and their interprotoplastic threads. As to the nature of the impulse, one can only hazard a meaningless guess that it may consist in a chain of chemical, catalytic or osmotic disturbances.

Two noteworthy attempts have been made to ascribe the function of transmission of impulses to specially differentiated structures. The first was by Haberlandt who dealt with the transmission of impulses in

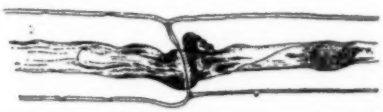

FIG. 4. ELONGATED ELEMENTS OF *Mimosa* SUPPOSED BY HABERLANDT TO TRANSMIT HYDROSTATIC IMPULSES.

Mimosa, the common 'sensitive plant' of the tropics, cultivated in conservatories. An impulse set up at the tip of a pinnule of one of these plants is conducted through petioles, stems and branches to a distance of a meter at a rate varying from 6 to 21 mm. per second. A study of the structure of the plant reveals the presence of a connected series of long tube-like cells in the fibro-vascular bundles, usually turgid, and containing relatively small protoplasts. It is argued that impulses take the form of hydrostatic disturbances communicated through the system

of tubes. This conclusion, however, disregards many well-known adverse facts. Thus it is possible to secure the conduction of an impulse through a section of stem, one or even two centimeters in length, which has been killed by a steam jacket and allowed to desiccate. Then again, when excised stems have been placed in connection with the most powerful force pumps, or the action of the strongest osmotic solutions, and artificial disturbances set up, no reactions were induced in the pinnules, although great hydrostatic movements must have been initiated. The above mentioned hypothesis must be declared 'not proven,' although it is a puzzling matter to attempt any suggestion of a method by which transmission could be accomplished through 2 cm. of dead tissues, and a meter of living tissue.

FIG. 5. FIBRILLAR STRUCTURES IN CELLS OF PLEROME OF ROOT OF ONION SUPPOSED BY NEMEC TO TRANSMIT IMPULSES.

Nemec finds a somewhat regular coincidence of fibrillar structures in the apical portions of roots, with the pathway which impulses should travel in passing from the perceptive region to the motor zones. The occurrence of these structures has been well known for some time, and the theory of their function as special transmitting organs has something in its favor, especially as these fibrillae have continuous intercellular communications. No facts are at hand to suggest the presence of these fibrillar organs in other members of the body.

The decentralized organization of the plant, the intimate and delicate morphogenic and physiologic correlations existing among all its members and its reflective system of irritability, make unnecessary, and preclude, the differentiation of transmitting tracts, except in certain narrowly specialized organs adapted to other than their typical vegetative purposes. The most recent hypothesis as to the geotropic action of the

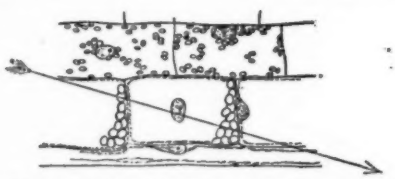

FIG. 6. STATOLITHIC ACTION OF CELLS OF STELAR SHEATH CONTAINING STARCH, BY THE AID OF WHICH EQUILIBRIUM IS SUPPOSED TO BE MAINTAINED.

plant is in accordance with these ideas. By this theory the maintenance of equilibrium is made possible by the appreciation of gravity as the result of the position of granules in sheath cells in every part of the body, these cells acting as statoliths and sending impulses to the motor zones of the organs in which they are found.

ON THE RECEPTION OF THE 'ORIGIN OF SPECIES.'*

By Professor HUXLEY.

TO the present generation, that is to say, the people a few years on the hither and thither side of thirty, the name of Charles Darwin stands alongside of those of Isaac Newton and Michael Faraday; and, like them, calls up the grand ideal of a searcher after truth and interpreter of Nature. They think of him who bore it as a rare combination of genius, industry, and unswerving veracity, who earned his place among the most famous men of the age by sheer native power, in the teeth of a gale of popular prejudice, and uncheered by a sign of favour or appreciation from the official fountains of honour; as one who in spite of an acute sensitiveness to praise and blame, and notwithstanding provocations which might have excused any outbreak, kept himself clear of all envy, hatred, and malice, nor dealt otherwise than fairly and justly with the unfairness and injustice which was showered upon him; while, to the end of his days, he was ready to listen with patience and respect to the most insignificant of reasonable objectors.

And with respect to that theory of the origin of the forms of life peopling our globe, with which Darwin's name is bound up as closely as that of Newton with the theory of gravitation, nothing seems to be further from the mind of the present generation than any attempt to

* In the last issue of The Popular Science Monthly the original announcement by Darwin and Wallace of the theory of organic evolution by natural selection was reprinted from the 'Journal' of the Linnean Society for 1858. The 'Origin of Species' was published on November 24, 1859; its reception by scientific men, by churchmen and by the general public forms one of the most interesting chapters in the history of science. We reproduce part of the account of the matter contributed by Huxley to 'The Life and Letters of Darwin' (1887), and extracts from the reviews published in 1860 in the 'Edinburgh Review,' attributed to Richard Owen, and in 'The American Journal of Science' by Louis Agassiz and Asa Gray. Regarding the Edinburgh reviewer Darwin wrote to Hooker: "Some of my relations say it cannot *possibly* be ————'s article, because the review speaks so very highly of ———. Poor dear simple folk." To Gray he wrote regarding the review quoted below: 'Your review seems to me *admirable;* by far the best that I have read,' and again to Wallace 'Asa Gray fights like a hero in defence.' Huxley also says that Gray 'fought the battle splendidly in the United States,' and ranks him with Hooker, Lubbock and himself. Gray's review in the 'American Journal' and his series of articles in the 'Atlantic Monthly' seem at this time, however, rather colorless and chiefly concerned in arguing that if evolution is true it does not conflict with natural theology.—Editor.

smother it with ridicule or to crush it by vehemence of denunciation. 'The struggle for existence,' and 'Natural selection,' have become household words and every-day conceptions. The reality and the importance of the natural processes on which Darwin founds his deductions are no more doubted than those of growth and multiplication; and, whether the full potency attributed to them is admitted or not, no one doubts their vast and far-reaching significance. Wherever the biological sciences are studied, the 'Origin of Species' lights the paths of the investigator; wherever they are taught it permeates the course of instruction. Nor has the influence of Darwinian ideas been less profound, beyond the realms of Biology. The oldest of all philosophies, that of Evolution, was bound hand and foot and cast into utter darkness during the millennium of theological scholasticism. But Darwin poured new life-blood into the ancient frame; the bonds burst, and the revivified thought of ancient Greece has proved itself to be a more adequate expression of the universal order of things than any of the schemes which have been accepted by the credulity and welcomed by the superstition of seventy later generations of men.

To any one who studies the signs of the times, the emergence of the philosophy of Evolution, in the attitude of claimant to the throne of the world of thought, from the limbo of hated and, as many hoped, forgotten things, is the most portentous event of the nineteenth century. But the most effective weapons of the modern champions of Evolution were fabricated by Darwin; and the 'Origin of Species' has enlisted a formidable body of combatants, trained in the severe school of Physical Science, whose ears might have long remained deaf to the speculations of *à priori* philosophers. * * *

If I confine my retrospect of the reception of the 'Origin of Species' to a twelvemonth, or thereabouts, from the time of its publication, I do not recollect anything quite so foolish and unmannerly as the 'Quarterly Review' article, unless, perhaps, the address of a Reverend Professor to the Dublin Geological Society might enter into competition with it. But a large proportion of Mr. Darwin's critics had a lamentable resemblance to the 'Quarterly' reviewer, in so far as they lacked either the will, or the wit, to make themselves masters of his doctrine; hardly any possessed the knowledge required to follow him through the immense range of biological and geological science which the 'Origin' covered; while, too commonly, they had prejudiced the case on theological grounds, and, as seems to be inevitable when this happens, eked out lack of reason by superfluity of railing.

But it will be more pleasant and more profitable to consider those criticisms, which were acknowledged by writers of scientific authority, or which bore internal evidence of the greater or less competency and, often, of the good faith, of their authors. Restricting my survey to a

twelvemonth, or thereabouts, after the publication of the 'Origin,' I find among such critics Louis Agassiz; Murray, an excellent entomologist; Harvey, a botanist of considerable repute; and the author of an article in the 'Edinburgh Review,' all strongly adverse to Darwin. Pictet, the distinguished and widely learned paleontologist of Geneva, treats Mr. Darwin with a respect which forms a grateful contrast to the tone of some of the preceding writers, but consents to go with him only a very little way. On the other hand, Lyell, up to that time a pillar of the anti-transmutationists (who regarded him, ever afterwards, as Pallas Athene may have looked at Dian, after the Endymion affair), declared himself a Darwinian, though not without putting in a serious *caveat*. Nevertheless, he was a tower of strength, and his courageous stand for truth as against consistency, did him infinite honour. As evolutionists, *sans phrase*, I do not call to mind among the biologists more than Asa Gray, who fought the battle splendidly in the United States; Hooker, who was no less vigorous here; the present Sir John Lubbock and myself.

DARWIN ON THE ORIGIN OF SPECIES.*

Such are the signs of defective information which contribute, almost at each chapter, to check our confidence in the teachings and advocacy of the hypothesis of 'Natural Selection.' But, as we have before been led to remark, most of Mr. Darwin's statements elude, by their vagueness and incompleteness, the test of Natural History facts. Thus he says:—

'I think it highly probable that our domestic dogs have descended from several wild species.' It may be so; but what are the species here referred to? Are they known, or named, or can they be defined? If so, why are they not indicated, so that the naturalist might have some means of judging of the degree of probability, or value of the surmise, and of its bearing on the hypothesis?

'Isolation, also,' says Mr. Darwin, 'is an important element in the process of natural selection.' But how can one select if a thing be 'isolated'? Even using the word in the sense of a confined area, Mr. Darwin admits that the conditions of life 'throughout such area, will tend to modify all the individuals of a species in the same manner, in relation to the same conditions.' (P. 104.)

No evidence, however, is given of a species having ever been created in that way; but granting the hypothetical influence and transmutation, there is no selection here. The author adds, 'Although I do not doubt that isolation is of considerable importance in the production of new species, on the whole, I am inclined to believe, that largeness

* From an article in the 'Edinburgh Review' for April, 1860, attributed to Richard Owen.

of area is of more importance in the production of species capable of spreading widely. (P. 105.)

Now, on such a question as the origin of species, and in an express, formal, scientific treatise on the subject, the expression of a belief, where one looks for a demonstration, is simply provoking. We are not concerned in the author's beliefs or inclinations to believe. Belief is a state of mind short of actual knowledge. It is a state which may govern action, when based upon a tacit admission of the mind's incompetency to prove a proposition, coupled with submissive acceptance of an authoritative dogma, or worship of a favorite idol of the mind. We readily concede, and it needs, indeed, no ghost to reveal the fact, that the wider the area in which a species may be produced, the more widely it will spread. But we fail to discern its import in respect of the great question at issue.

We have read and studied with care most of the monographs conveying the results of close investigations of particular groups of animals, but have not found, what Darwin asserts to be the fact, at least as regards all those investigators of particular groups of animals and plants whose treatises he has read, viz., that their authors 'are one and all firmly convinced that each of the well-marked forms or species was at the first independently created.' Our experience has been that the monographers referred to have rarely committed themselves to any conjectural hypothesis whatever, upon the origin of the species which they have closely studied.

Darwin appeals from the 'experienced naturalists whose minds are stocked with a multitude of facts' which he assumes to have been 'viewed from a point of view opposite to his own,' to the 'few naturalists endowed with much flexibility of mind,' for a favourable reception of his hypothesis. We must confess that the minds to whose conclusions we incline to bow belong to that truth-loving, truth-seeking, truth-imparting class, which Robert Brown, Bojanus, Rudolphi, Cuvier, Ehrenberg, Herold, Kölliker, and Siebold, worthily exemplify. The rightly and sagaciously generalizing intellect is associated with the power of endurance of continuous and laborious research, exemplarily manifested in such monographs as we have quoted below. Their authors are the men who trouble the intellectual world little with their beliefs, but enrich it greatly with their proofs. If close and long-continued research, sustained by the determination to get accurate results, blunted, as Mr. Darwin seems to imply, the far-seeing discovering faculty, then are we driven to this paradox, viz., that the elucidation of the higher problems, nay the highest, in Biology, is to be sought for or expected in the lucubrations of those naturalists whose minds are not weighted or troubled with more than a discursive and superficial knowledge of nature.

PROFESSOR AGASSIZ ON THE ORIGIN OF SPECIES.*

Since the arguments presented by Darwin in favor of a universal derivation from one primary form, of all the peculiarities existing now among living beings have not made the slightest impression on my mind, nor modified in any way the views I have already propounded, I may fairly refer the reader to the paragraphs alluded to above as containing sufficient evidence of their correctness, and I will here only add a single argument, which seems to leave the question where I have placed it.

It seems to me that there is much confusion of ideas in the general statement of the variability of species so often repeated lately. If species do not exist at all, as the supporters of the transmutation theory maintain, how can they vary? and if individuals alone exist, how can the differences which may be observed among them prove the variability of species? The fact seems to me to be that while species are based upon definite relations among individuals which differ in various ways among themselves, each individual, as a distinct being, has a definite course to run from the time of its first formation to the end of its existence, during which it never loses its identity nor changes its individuality, nor its relations to other individuals belonging to the same species, but preserves all the categories of relationship which constitute specific or generic or family affinity, or any other kind or degree of affinity. *To prove that species vary it should be proved that individuals born from common ancestors change the different categories of relationship which they bore primitively to one another.* While all that has thus far been shown is, that there exists a considerable difference among individuals of one and the same species. This may be new to those who have looked upon every individual picked up at random, as affording the means of describing satisfactorily any species; but no naturalist who has studied carefully any of the species now best known, can have failed to perceive that it requires extensive series of specimens accurately to describe a species, and that the more complete such series are, the more precise appear the limits which separate species. Surely the aim of science cannot be to furnish amateur zoölogists or collectors a *recipe* for a ready identification of any chance specimen that may fall into their hands. And the difficulties with which we may meet in attempting to characterize species do not afford the first indication that species do not exist at all, as long as most of them can be distinguished, as such, almost at first sight. I foresee that some convert to the transmutation creed will at once object that the facility with which species may be distinguished is no evidence that they were not derived from other species. It may be so.

* From a review in 'The American Journal of Science and Arts,' July, 1860.

But as long as no fact is adduced to show that any one well-known species among the many thousands that are buried in the whole series of fossiliferous rocks, is actually the parent of any one of the species now living, such arguments can have no weight; and thus far the supporters of the transmutation theory have failed to produce any such facts. Instead of facts we are treated with marvelous bear, cuckoo, and other stories. Credat Judaeus Apella!

Had Mr. Darwin or his followers furnished a single fact to show that individuals change, in the course of time, in such a manner as to produce at last species different from those known before, the state of the case might be different. But it stands recorded now as before, that the animals known to the ancients are still in existence, exhibiting to this day the characters they exhibited of old. The geological record, even with all its imperfections, exaggerated to distortion, tells now, what it has told from the beginning, that the supposed intermediate forms between the species of different geological periods are imaginary beings, called up merely in support of a fanciful theory. The origin of all the diversity among living beings remains a mystery as totally unexplained as if the book of Mr. Darwin had never been written, for no theory unsupported by fact, however plausible it may appear, can be admitted in science.

It seems generally admitted that the work of Darwin is particularly remarkable for the fairness with which he presents the facts adverse to his views. It may be so; but I confess that it has made a very different impression upon me. I have been more forcibly struck by his inability to perceive when the facts are fatal to his argument, than by anything else in the whole work. His chapter on the Geological Record, in particular, appears to me, from beginning to end, as a series of illogical deductions and misrepresentations of the modern results of Geology and Palæontology. I do not intend to argue here, one by one, the questions he has discussed. Such arguments end too often in special pleading, and any one familiar with the subject may readily perceive where the truth lies by confronting his assertions with the geological record itself. But since the question at issue is chiefly to be settled by palæontological evidence, and I have devoted the greater part of my life to the special study of the fossils, I wish to record my protest against his mode of treating this part of the subject. Not only does Darwin never perceive when the facts are fatal to his views, but when he has succeeded by an ingenious circumlocution in overleaping the facts, he would have us believe that he has lessened their importance or changed their meaning.

REVIEW OF DARWIN'S THEORY ON THE ORIGIN OF SPECIES BY MEANS OF NATURAL SELECTION.

BY ASA GRAY.*

We are thus, at last, brought to the question; what would happen if the derivation of species were to be substantiated, either as a true physical theory, or as a sufficient hypothesis? What would come of it? The enquiry is a pertinent one, just now. For, of those who agree with us in thinking that Darwin has not established his theory of derivation, many will admit with us that he has rendered a theory of derivation much less improbable than before; that such a theory chimes in with the established doctrines of physical science, and is not unlikely to be largely accepted long before it can be proved. Moreover, the various notions that prevail,—equally among the most and the least religious,—as to the relations between natural agencies or phenomena and Efficient Cause, are seemingly more crude, obscure, and discordant than they need be.

It is not surprising that the doctrine of the book should be denounced as atheistical. What does surprise and concern us is, that it should be so denounced by a scientific man, on the broad assumption that a material connection between the members of a series of organized beings is inconsistent with the idea of their being intellectually connected with one another through the Deity, *i. e.*, as products of one mind, as indicating and realizing a preconceived plan. An assumption the rebound of which is somewhat fearful to contemplate, but fortunately one which every natural birth protests against. * * *

We wished under the light of such views, to examine more critically the doctrine of this book, especially of some questionable parts;—for instance, its explanation of the natural development of organs, and its implication of a "necessary acquirement of mental power" in the ascending scale of gradation. But there is room only for the general declaration that we cannot think the Cosmos a series which began with chaos and ends with mind, or of which mind is a result; that if by the successive origination of species and organs through natural agencies, the author means a series of events which succeed each other irrespective of a continued directing intelligence,—events which mind does not order and shape to destined ends,—then he has not established that doctrine, nor advanced towards its establishment, but has accumulated improbabilities beyond all belief. Take the formation and the origination of the successive degrees of complexity of eyes as a specimen. The treatment of this subject (pp. 188, 189), upon one interpretation is open to all the objections referred to; but if, on the other

* From a review in 'The American Journal of Science and Arts,' March, 1860.

hand, we may rightly compare the eye "to a telescope, perfected by the long continued efforts of the highest human intellects," we could carry out the analogy, and draw satisfactory illustrations and inferences from it. The essential, the directly intellectual thing is the making of the improvements in the telescope or the steam-engine. Whether the successive improvements, being small at each step, and consistent with the general type of the instrument, are applied to some of the individual machines, or entire new machines are constructed for each, is a minor matter. Though if machines could engender, the adaptive method would be most economical; and economy is said to be a paramount law in nature. The origination of the improvements, and the successive adaptations to meet new conditions or subserve other ends, are what answer to the supernatural, and therefore remain inexplicable. As to bringing them into use, though wisdom foresees the result, the circumstances and the natural competition will take care of that, in the long run. The old ones will go out of use fast enough, except where an old and simple machine remains still best adapted to a particular purpose or condition,—as, for instance, the old Newcomen engine for pumping out coal-pits. If there's a Divinity that shapes these ends, the whole is intelligible and reasonable; otherwise, not.

We regret that the necessity of discussing philosophical questions has prevented a fuller examination of the theory itself, and of the interesting scientific points which are brought to bear in its favor. One of its neatest points, certainly a very strong one for the local origination of species, and their gradual diffusion under natural agencies, we must reserve for some other convenient opportunity.

The work is a scientific one, rigidly restricted to its direct object; and by its science it must stand or fall. Its aim is, probably not to deny creative intervention in nature,—for the admission of the independent origination of certain types does away with all antecedent improbability of as much intervention as may be required,—but to maintain that Natural Selection in explaining the facts, explains also many classes of facts which thousand-fold repeated independent acts of creation do not explain, but leave more mysterious than ever. How far the author has succeeded, the scientific world will in due time be able to pronounce.

SCIENTIFIC LITERATURE.

THE AGRICULTURAL YEARBOOK.

THE Yearbook of the United States Department of Agriculture has taken rank as one of the important annuals of this country, and in point of circulation is hardly equaled. This is due to the munificence of the Federal Government in appropriating $300,000 annually for its publication, in an edition of half a million copies, and to the care which is given by the Department of Agriculture to the preparation of timely and interesting articles and appropriate illustrations. The Yearbook takes the place of the annual report of the Secretary, which was naturally a more formal document and less likely to attract the average reader's attention. In its present form it presents an attractive appearance, and its many illustrations and long list of short articles on a variety of subjects invite attention. The volume for 1900 comprises nearly nine hundred pages, and is illustrated by eighty-seven plates, nine of them colored, and eighty-eight text figures. In addition to the executive reports, which occupy less than eighty pages, it contains thirty-one articles on various phases of the Department's work or other subjects of direct interest to agriculture. Only a part of these can be mentioned, but enough to indicate the range of subjects and that the volume is not alone of interest and value to the farmers of the country. In an article on Smyrna fig culture in the United States, Dr. Howard describes the successful introduction by the Department of the Blastophaga, the insect which fertilizes the fig and has enabled the production of Smyrna figs of good quality in this country; and one on the date palm tells what has been done for the promotion of that industry by the introduction of the best varieties into Arizona, where it flourishes even in soils heavily impregnated with alkali. Wheat growing in the semi-arid districts has been rendered less uncertain, it is thought, by the introduction of macaroni and several other varieties of wheat, which have already given promise. Articles on the food of nestling birds and how birds affect the orchard illustrate the practical bearings of a phase of work which is concerned with the food habits of birds under different conditions, to ascertain what kinds are beneficial and what injurious to the farmer and fruit grower; while one on the food value of the potato gives some practical results of the work of the Department in another direction. There are two articles on practical forestry and forest extension, several on injurious insects and their repression, a helpful one on practical irrigation, two on road building, in which subject the Department is taking an active interest, and two on meteorology. One of the latter, on hot waves, the conditions which produce them and their effects on agriculture, is of special interest even though it does not suggest any relief. The free rural delivery of mails, although in no way connected with the Department of Agriculture, comes so close to its farmer constituents that an account of the working of that system does not seem out of place in its Yearbook. The four thousand routes now in operation provide for the daily delivery of mail at the scattered homes of about three and a half million of rural population. The work done in a long life devoted to agriculture, horticulture and kindred subjects by the late William Saunders, who had been connected with the Department since its establishment in 1862, is the subject of a short sketch,

and his portrait occupies the place of honor as the frontispiece to the volume. An appendix of over 200 pages contains a vast amount of condensed information on a variety of subjects, and bears out the inference that no effort has been spared to make this, like the preceding volumes, worthy of the large expenditure involved and the wide distribution it is given.

METEOROLOGY.

A WELL-ARRANGED, readable and generally satisfactory presentation of the principles of meteorology may be found in the latest text-book on that subject, Börnstein's *Leitfaden der Wetterkunde.* The general plan of the book is conventional, but there are one or two features which deserve special mention. In the introduction an interesting figure shows the 'thermo-isopleths' for Berlin, these lines indicating, in one drawing, both the diurnal and the annual march of the air temperature. In the chapter on temperature all important matters are considered, including the recent work of Pettersson and Meinardus on long-range forecasts for Europe based on the special characteristics of the Gulf Stream, and a brief summary of the meteorological results of the international balloon ascents, in some of which the author took part. The physiological effects of atmospheric humidity receive some consideration, and a new table is given showing, for a number of stations, the probable fall of temperature below the wet-bulb reading of an afternoon hour, to be expected during the night. This table is useful in predicting frost. The much-agitated question of hail prevention by cannon firing is briefly taken up in the sections on rainfall. The chapter on weather is very complete. Thunderstorm charts and theories; the weather types of van Bebber and Köppen, and the weather services of the world, are all discussed, the weather types being fully illustrated. A noteworthy feature of the work is the nine colored views of cloud types, similar to those in the International Cloud Atlas. This is the first text-book to have such elaborate illustrations of clouds. A fairly good working bibliography is appended, which includes comparatively few works in English. The index is good, but the chapters are not numbered, and there are no section headings in the text.

PSYCHOLOGY.

'AN Introduction to Psychology,' by Mary Whiton Calkins (The Macmillan Company), is one of the text-books in psychology that makes it obvious that psychology is to a great extent all things to all men. The books do not present the same body of accepted truth, varying only in such matters as arrangement and adaptation to students of different capacities and different practical needs. Changing your psychology book is not so much changing your coat as changing your skin. Miss Calkins, for instance, includes the study of 'the conscious relation of the human self to a divine self' as a sample of certain mysterious relationships between selves apart from those due to physical agencies. She includes a sympathetic discussion of the phenomena of telepathy and veridical hallucinations. Many of her co-workers would rigorously exclude both these topics. She makes no mention of the instructive reactions which are the *fons et origo* of our later intellects and wills or of the law of habit which would seem to many to be the key to comprehension of mental processes. Yet Miss Calkins's book is as scholarly and fair an exposition of the elements of psychology as any of the recent books. Those who seek from psychology training in analysis and discrimination and approach the study from an interest in general philosophy will find it a particularly helpful manual.

THE PROGRESS OF SCIENCE.

PROFESSOR RUDOLF VIRCHOW.

THE eightieth birthday of one of the leaders of modern civilization has been celebrated with imposing ceremonies at Berlin. Virchow is the founder of the science of pathology, and his services for anthropology have been nearly as great. He has not only demonstrated that the scientific research of the laboratory may be directly beneficial to mankind, but he has himself applied his own discoveries for the welfare of Berlin and of the German army, whence they have extended to the whole world. There is no city whose inhabitants are not healthier and happier because Virchow has lived and worked; it is indeed scarcely an exaggeration to say that there is no patient of any village physician who does not benefit from the labors of this man whose name he may never have heard. Virchow often stood opposed to Bismarck; in written history the iron chancellor may always be the more frequently named, but the world's progress has probably been more directly led by the man of science.

The ceremonies at Berlin included the presentation of a marble bust of Virchow to the great Pathological Institute founded by him; the presentation of an additional endowment to the Virchow Fund for the promotion of research, toward which the municipality contributed $20,000; the presentation of addresses of congratulation on behalf of the empire, state and municipality, and from national and foreign institutions, and, most interesting of all, a lecture by Virchow on the history and scope of pathology. Lord Lister, who represented the Royal Society and other British institutions, said: "All these bodies join in recognition of your gigantic intellectual powers, in gratitude for the great benefits that you have conferred upon humanity, and in admiration of your personal character, your absolute uprightness, the courage which has enabled you always to advocate what you believed to be the cause of truth, liberty and justice, and the genial nature which has won for you the love of all who know you. The astonishing vigor which you displayed in the address to which we listened today justifies the hope that, when many of us your juniors shall have been removed from this scene of labor, it may be granted to you to celebrate your ninetieth birthday not only in health and honor but in continued activity in the service of mankind."

THE YALE BICENTENNIAL EXERCISES.

UNIVERSITIES are among the most stable of institutions. Glasgow University recently celebrated its ninth jubilee, while Harvard University commemorated in 1886 the two hundred and fiftieth anniversary of its foundation. Yale University, the third in age of our American colleges, is now two hundred years old and the event has been celebrated in a manner commensurate with the prestige of the institution. Such occasions are almost medieval in their gowned processions, the presentation of Latin addresses, the conferring of degrees and the like; but they are nearly as modern as football games, in so far as they serve as an occasion of collecting endowments, attracting students and arousing the loyalty of alumni. Both in its dramatic exhibition and in its financial outcome the celebration at New Haven was eminently successful. There were

present thousands of graduates and guests for whom a program lasting four days had been prepared. It included sermons, addresses, concerts, dedications and other exercises, leading to the commemorative exercises and the conferring of honorary degrees. The doctorate of laws was conferred on President Roosevelt and forty-six others, including among scientific men J. S. Billings, director of the New York Public Library; S. P. Langley, secretary of the Smithsonian Institution; A. A. Michelson, professor of physics in the University of Chicago; William Osler, professor of medicine in the Johns Hopkins Medical School; Henry Smith Pritchett, president of the Massachusetts Institute of Technology; Ira Remsen, president of the Johns Hopkins University; Ogden Nicholas Rood, professor of physics in Columbia University, and Wilhelm Waldeyer, professor of anatomy in the University of Berlin.

About half of those who have become eminent for public services are college graduates, and Yale has certainly contributed its full share. The addresses by ex-President Gilman on Yale's Relation to Letters and Science, and by Professor Welch on Yale's Relation to Medicine, told of the important part taken by Yale's graduates in the scientific work of the country. Through the influence of the elder Silliman and the 'American Journal of Science,' established by him in 1818, and through the Sheffield Scientific School, Yale has always led in the sciences. Its faculty has included the two Sillimans, Olmsted, Loomis, Dana, Newton and Marsh, and among its alumni are many of those who have advanced science, including two of our leading inventors, Whitney and Morse. In education Yale has had great influence through the college presidents it has trained. As President Northrop pointed out in his address, one hundred and five graduates of Yale have been president of a college; and eighty-five different colleges have at some time had a Yale graduate for president. Yale furnished the first president of at least seventeen colleges—Princeton, Columbia, Dartmouth, Georgia, Williams, Hamilton, Kenyon, Illinois, Wabash, Missouri, Wisconsin, Beloit, California, Cornell, Western Reserve, Johns Hopkins and Chicago.

NOTES FROM THE BERLIN MEETING OF THE INTERNATIONAL ZOOLOGICAL CONGRESS.

The fifth meeting of the International Zoological Congress, which opened at Berlin on August 13, was attended by a very large number of zoologists and carried out an elaborate program in the course of which many highly interesting papers were read. The general sessions of the Congress were occupied by a series of addresses on general topics, among which may be mentioned those of Professor Yves Delage, of Paris on the fertilization of the egg, of Professor Grassi of Rome on the malaria organism, of Professor Poulton of Oxford on mimicry in insects, and the fine closing address on vitalism and mechanism by Professor Bütschli of Heidelberg. The number of detailed papers read in the various sections is too great to allow of their review here, but attention may be called to the interesting discussion on vitalism and mechanism that took place in the opening session of the section for experimental biology. The modern revival of interest in this time-honored problem, which occupied so large a field of discussion a half-century ago, has been largely due to the surprising results attained by experimental embryology during the last decade, especially those brought forward by Roux, Driesch and their many followers. The discussion at Berlin was opened by Driesch himself in a paper entitled 'Two New Proofs of Vitalism,' a title which indicates his own position on the general problem. Presenting in brief

form the essential arguments that he had already put forward in more extended papers on the development of fractional parts of the egg and on the general problem of the localization of morphogenic processes, Driesch maintained that these processes have no true analogue in the inorganic world, are insoluble by any purely mechanical or physico-chemical hypothesis, and hence form a problem *sui generis*. The most characteristic operations of the living organism, more especially those concerned in the processes of regeneration, regulation and the like, fail of adequate interpretation on the so-called 'machine-theory' of life, and must be regarded from a vitalistic as opposed to a mechanistic standpoint. His conclusions, which were stated with great lucidity and force, met with strong opposition in the animated controversy that followed, in which a number of eminent embryologists participated. Some of these speakers wholly denied the validity of Driesch's reasoning and endeavored to show that true analogues to regulative phenomena occur in purely physical processes. Others, notably Professor Roux, took more cautious ground, maintaining that despite our present inability to explain or even to conceive the nature of some of the most striking and characteristic phenomena of development, we are by no means justified in taking refuge behind such a word as 'vitalism,' which carries with it so many misleading connotations from the earlier period when it was employed in connection with the exploded hypothesis of a specific 'vital force.'

The masterly and scholarly address of Professor Bütschli, delivered before the general session, contained not only a specific examination of the main facts in which Driesch's position rests, but also a critical study of more abstract conceptions, such as those embodied in the words 'mechanism,' 'causality' and the like, which are inevitably involved in the discussion of the subject. This address, which has been published in pamphlet form by Engelmann of Leipzig under the title *Mechanism and Vitalism* is worthy of attentive study, not only by students of zoology, but also by all who are interested in the more general aspects of scientific progress. Recognizing the difficulties that the mechanistic interpretation of organic nature has to encounter, Bütschli nevertheless expresses the judgment that, in the broad sense of the phrase, it is the only one under which scientific investigation is possible, and that it is, to say the least, wholly premature to speak of 'proofs of vitalism.' "The phenomena involved in the localization process seem to me not to differ fundamentally in kind from those occurring in the inorganic world." The acceptance of vitalistic hypothesis constitutes a backward step in scientific method. "Both the old and the new vitalism have done no more than to emphasize the unsolved riddles that confront us and to throw doubt on the possibility of their explanation on a mechanistic basis. The assumption of vitalistic processes involves the admission that they are ultimate phenomena, in themselves inexplicable, that we are not able to subsume under general laws. Hence we must take the ground that in vital phenomena we can comprehend only that which may receive a physico-chemical explanation." How far the mechanistic hypothesis will succeed in the explanation of vital phenomena, only the future will show. 'By their fruits ye shall know them.'

In considering the possibility of a mechanistic explanation of the purposive or teleological aspect of living organisms Bütschli recognizes Darwin's theory of natural selection as the sole fruitful attempt in this direction. In view of the difficulties that have been urged against that theory, and especially the drastic criticism it has received at the hands of some German writers, it is interesting to find that

so competent and critical an authority as Bütschli accepts Darwin's explanation, as amplified by later workers, not only as a possible one, but also as the most probable one thus far advanced.

THE EFFECT OF SECULAR COOLING AND METEORIC DUST ON THE LENGTH OF THE DAY.

It is well known that the day, or interval required for one complete rotation of the earth, is the time unit by which the succession of terrestrial and celestial events is measured. The earth revolves with a regularity which far surpasses that of the best clocks and chronometers except for short intervals of time, such as a few minutes, or a few hours at most. But it is not certain that the day has been of the same length in the remote past as at present, or that it will remain of the same length in the distant future. It is therefore a matter of prime importance, especially in those branches of astronomy which deal with long intervals of time, to understand the effects of such secular causes as may tend to modify the length of the day. In a recent number of the 'Astronomical Journal' Professor R. S. Woodward has published a mathematical investigation of the effects of secular cooling and of accumulations of meteoric dust. The cooling, and consequent cubical contraction, of the earth tends to shorten the day; while the increment to the earth's mass from meteorites, of which not less than twenty millions daily fall into the atmosphere, tends to lengthen the day.

The effect of secular cooling was considered to a limited extent by Laplace in his 'Mécanique céleste.' Assuming that the earth is in the last stages of cooling he reached the conclusion that the length of the day has not changed appreciably in the past two thousand years. Without making any assumption as to the present stage in the history of cooling, Woodward shows that during no interval so short as twenty centuries in the entire history of cooling can the length of the day change by so much as a thousandth of a second from the cause in question. In fact, so slowly does the effect of secular cooling accumulate that the day will not change, or has not changed, as the case may be, by so much as a half second in the first ten million years after the earth began to solidify and to lose heat by conduction through its crust. On the other hand, the shortening of the day which must come with the end of the process of cooling is a very sensible fraction of its present length. For this total effect Woodward gives a remarkably simple expression, namely: the ratio of the change in length of the day to its initial length is equal to two-thirds of the product of the fall in temperature of the earth by its cubical contraction. Supposing the earth to have been initially at a temperature of 3000°C., and that its cubical contraction is the same as that of iron, or about 3×10^{-5}, it follows that the day will be ultimately shortened by about six per cent. of its initial length, or by an hour and a half nearly. The length of time required by the earth to cool down sensibly to the temperature of surrounding space is very great. Nothing short of a million years is suitable as a time unit for measuring the historical progress of such events. Thus Woodward shows that it will require about three hundred thousand million years for the earth to accomplish ninety-five per cent. of its contraction, and that after a million million years its contraction would no longer sensibly affect the length of the day.

To what extent is this shortening of the day due to contraction offset by the lengthening due to accessions of meteoric dust? The calculation shows that the accumulation of such dust goes on so slowly that its effect will not become perceptible until the total effect from secular cooling is nearly complete. In round numbers, the latter effect goes on two hundred thousand times as

fast as the opposite effect from meteoric dust. In fact, if the average mass of meteorites is no greater than one gram, it will require a million million years, at the present rate of influx, to lengthen the day by so much as a quarter of a second.

It is clear, therefore, that, if the regularity of the earth as a timekeeper during historic times is to be questioned, one must look to other causes than secular cooling and meteoric dust.

ENGLAND'S CHEMICAL INDUSTRY.

THERE has been much agitation in England during the last few years over the fact that Germany is steadily forging ahead in all lines of chemical industry. As long ago as 1886, Professor Mendola, in a paper read before the Society of Arts, reviewed the English color industry, and sounded a warning note regarding its future progress. English manufacturers have, however, manfully stood by their old methods, and are seeing their trade gradually, but surely slipping from their grasp.

At the Glasgow meeting of the British Association, Arthur C. Green, who is well qualified to speak on the subject, read a paper on the relative progress of the coal-tar industry in England and Germany during the last fifteen years, in which he handles the matter with almost brutal frankness. After sketching the wonderful advancement which has been made in the development of the industry during the period covered by his paper, the discovery of thousands of new dyestuffs, the introduction of hundreds of new synthetic pharmaceutical products and the great advances in the production and design of chemical plant, occasioned by the vast requirements of the industry, he brings out the comparative statistics of the industry in the two countries. Among them the following are worthy of reproduction. The exports of coal-tar colors, exclusive of alizarin, from Germany have increased from 4,646 tons in 1885 to 17,639 tons in 1899; those of anilin oil and salt from 1,713 tons in 1885 to 7,135 in 1895, and of alizarin colors from 4,284 to 8,927 tons in the same period. The values of the coal-tar colors exported increased from 2,600,000 pounds sterling in 1894 to 3,500,000 pounds in 1898. In fifteen years the imports of coal-tar dyestuffs into England have increased fifty per cent., while the exports from England have decreased over thirty per cent. The Bradford Dyers' Association uses at present 80% German coloring-matters and only 10% English. The British Cotton and Wool Dyers' Association imports 78% of its anilin colors and over 98% of its alizarin colors. The English Sewing Cotton Company used, out of a total of sixty tons of coloring-matters, only 9% of English manufacture. In addition to this, the indigo industry, which now yields to India an income of three million pounds sterling a year, is seriously threatened by the synthetic indigo from Germany, and its days are in all probability numbered.

The cause of this state of affairs Mr. Green finds in the almost utter inappreciation of science on the part of the English Government, manufacturers and people. As he says, 'it is not so much the education of our chemists which is at fault as the scientific education of the public as a whole.'

This theme has more than an indirect bearing upon American industries. We are just beginning to reap the harvest which awaits us in the application of scientific principles to our industries. Until recently we have been following the English 'rule o' thumb' method, but along many lines there has now been a radical change, and in these England is finding her commercial supremacy threatened from this side of the water. There are yet enormous fields for us to conquer, in which we have a great advantage over Germany in the natural resources of the country. The enormous industrial strides which this country is taking,

which command the admiration as well as the fear of the world, are after all the fruitage of the ideas which the teachers of science in our colleges and technological schools have been pounding into the often unwilling brains of their students during the last quarter of a century.

SCIENTIFIC ITEMS.

DR. RICHMOND MAYO-SMITH, professor of political economy and social science at Columbia University died as the result of a fall on November 11.—A memorial meeting in honor of the late Henry Augustus Rowland was held at the Johns Hopkins University, on October 16. The principal address was made by Dr. T. C. Mendenhall.

THE Rumford medals of the American Academy of Arts and Sciences have been presented to Professors Carl Barus and Elihu Thomson.—Professor Geo. J. Brush, emeritus professor of mineralogy and formerly director of the Sheffield Scientific School of Yale University, received a loving cup from his former students, on the occasion of the recent bicentennial exercises.

THE second annual Huxley lecture of the Anthropological Institute was delivered by Dr. Francis Galton, F.R.S., on October 29, his subject being 'The Possible Improvement of the Human Breed under the Existing Conditions of Law and Sentiment.'

PROFESSOR HUGO MÜNSTERBERG, of Harvard University, began, on November 11, a series of eight Lowell lectures at the Massachusetts Institute of Technology, on 'The Results of Experimental Psychology.'

MR. ANDREW CARNEGIE has given an additional million dollars towards the endowment of the Carnegie Institute, Pittsburg, and a second million dollars for the Polytechnic Institute to be established in that city.—Mr. T. Jefferson Coolidge, late Minister to France, has given a fund of $50,000 to the Jefferson Physical Laboratory of Harvard University for physical research.—Mr. John D. Rockefeller has promised to contribute $200,000 toward the endowment fund for Barnard College, Columbia University, provided that an equal sum is given by others before January 1, 1902.—The preliminary plans have been accepted for a new building for the Department of Agriculture at Washington. These plans contemplate a marble structure, something over 300 feet long, with wings at either end extending to the rear to accommodate the various laboratories of the department.